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Research paper

The Effects of the TPACK-P Educational Program on Teachers' TPACK: Programming as a Technological Tool

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Abstract

Background/Objectives: This study examined the effects of introducing programming as a technological tool for teachers' Technological Pedagogical Content Knowledge (TPACK) development.
Methods/Statistical Analysis: Thirty-two teachers were divided into two groups, completing different types of TPACK educational programs. The control group's TPACK training program was based on information and communication technology (ICT), while that of the experimental group was based on programming. To verify the effectiveness of the TPACK training program, tests were administered before and after the educational program. A statistical analysis of questionnaire results also investigated changes resulting from TPACK.
Findings: Both the control and experimental groups showed statistically significant improvements in the post-test compared with the pre-test. However, in the detailed areas of TPACK by group, the improvements in the two groups differed. Unlike the control group, the experimental group showed a statistically significant improvement in the knowledge related to technology. This result illustrated that programming is effective in solving the problem of integrating technology into the classroom. In contrast, there was no significant difference in the post-test, as this was applied in the short term. However, programming has been shown to affect Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and TPACK. In summary, the results showed that a TPACK educational program based on programming is effective for teachers' TPACK development.
Improvements/Applications: A training method is needed for applying programming in TPACK education. In addition, complementary research on the TPACK-P education programis required.

***Keywords:** TPACK, In-service teacher, Programming, TPACK-P, Educational program*

1. Introduction

At the World Economic Forum in 2016, many presenters made clear that society, the economy, and human life will develop in ways that have never been experienced before due to advanced technology [1].The importance of technology has increased, and a The New Media Consortium (NMC) (2017) report stated that various efforts are needed to introduce this rapidly changing technology into the classroom [2].
Recently, technology integration into the classroom has been an extremely interesting issue in education. Technology has been identified as a means of overcoming the limitations of existing education and encouraging students' effective learning [3]. Many researchers have studied various ways of promoting learning by introducing technology. In recent research, researchers have sought to develop the necessary technological tools to suit the educational environment and measure their effects [4]. However, although the technological tools are constantly evolving, their use has remained almost unchanged. In short, while technology has developed, teachers have not been able to use it effectively in class [5].
The main reason for this problem is that teachers lack knowledge about technology. They do not have sufficient understanding to utilize technology properly; moreover, they lack the ability to design lessons using technology and teach the classes to students. To solve this problem, Koehler and Mishra (2006) proposed TPACK, a form of Technological Knowledge (TK) integrated in Pedagogical Content Knowledge (PCK) proposed by Shulman (1986) [6,7]. TPACK is a knowledge-based technology that enables teachers to design and conduct the lessons needed for curriculum content while considering the educational context. As the importance of technology has increased, TPACK's significance has also risen [8]. As a result, studies have been actively carried out to establish the TPACK theory by subject. In recent years, studies applying TPACK education programs to in-service and preservice teachers have been actively conducted [9].
In TPACK, there is a comprehensive understanding of technological tools, ranging from pencils used in classrooms to ICT tools, smart pads, and blackboards. However, here, the technological tools were developed primarily to perform certain functions. Therefore, there are functional limitations to these tools, and there are many difficulties associated with utilizing the min the class in various educational contexts. Thus, Choi and Lee (2015) determined that the scope of technological tools should be extended to programming languages like C and Python. Programming allows teachers to create desired programs according to the educational context and utilize them in class. Therefore, programming is not a context-neutral tool, and it can solve the problems of existing technological tools [10].
Kim and Lee (2017) developed educational models and programs to carry out TPACK training based on programming [11]. In addition, they confirmed that programming languages are more

effective for preservice teachers' TPACK development than ICT tools are by offering the education program to these teachers. These studies were not conducted on teachers who were already employed in schools. Therefore, the effects of the TPACK-P education program on the teachers' TPACK change was analyzed by involving teachers in the TPACK-P educational program.

2. The TPACK-P Educational Program

As interest toward TPACK has increased, extensive research on TPACK has been conducted. Park and Kang (2014) validated the TPACK test tool developed by Chai et al. (2013) and explored the TPACK cognitive pathway for teachers using the exploratory factor method [12,13]. This study confirmed that TPACK directly affects Pedagogical knowledge (PK), TPK, and TCK in TPACK education.
Nah and Song (2014) analyzed TPACK research trends and proposed a TPACK education model in science education. They found that the initial TPACK research focused on the development of the TPACK educational program or method, but the trend had shifted toward verifying the training program [14].In addition, Sung and Cho (2012) analyzed the TPACK formation process of teachers in a social studies class. Using digital textbooks as a technological tool in the research, the teachers maximized student autonomy in classroom activities using technology, but they controlled students' behavior concerning technology use [15].According to Kim (2017), most of the TPACK studies were devoted to quantitative research. In addition, they were usually conducted by teachers and prospective teachers. Therefore, it is necessary to observe TPACK changes through qualitative research [16].
Ryu and Lee (2017) considered an online teacher-learning community connected with teaching practice for elementary school preservice teachers and verified the preservice teachers' TPACK change, which occurred through teaching practice. In this study, they showed that PCK and TPACK improved when teachers and preservice teachers formed a community together [17].Lee, Kim, and Kim (2018) conducted research on developing Computational Thinking(CT)-based teaching materials by introducing 'Desmos' into the physics curriculum. In this study, they demonstrated TPACK changes in preservice and in-service teachers and developed a CT-based education program in the physics subject in the secondary school curriculum [18].
As the importance of programming increases, research has been conducted to introduce programming into various subjects. Choi, Lee and Paik (2014) confirmed that the students'interest improved when programming was introduced in an elementary school science class [19]. Moreover, Noh and Paik (2015) confirmed the improvement of students'scientific inquiry ability by introducing programming in a high school science class [20]. Mun, Mun, Kim, and Kim (2016) analyzed the attitude and perception changes that occurred when science learning programming and physical computing were introduced in a high school class [21]. These studies confirmed that various abilities were improved when programming was introduced in various subjects.
TPACK research has been actively conducted to introduce programming. In the traditional TPACK education program, technological tools have been used in a context-neutral position, and there are many limitations associated with using technology (Kim, 2017) [22]. Therefore, Choi, Lee, and Lee (2015) stated that the scope of technology should be extended to programming to overcome the limitations of technological tools [23].Kim and Lee (2017) developed the TPACK-P educational model, which incorporates programming as a technological tool in TPACK. In addition, the TPACK-P education program was developed based on this model, and its effects were verified by applying it to preservice teachers [11]. The study of introducing programming in TPACK was conducted for preservice teachers, but not in-service teachers.

3. Methods

3.1 Research Procedure

In this study, the effects of the TPACK-P education program on teachers' TPACK was investigated. To accomplish this, the teacher participants were divided into an experimental group and control group. The TPACK-P education program was applied to the experimental group, and the TPACK education program was applied to the control group. To observe the teachers' TPACK changes, the participants completed a test before and after the TPACK educational program. By analyzing the pre- and post-test results, the effect of the TPACK-P education program on the teachers' TPACK was illustrated.

3.2 Participants

In this study, the subjects were 32 teachers, and each group consisted of 16 teachers. Each group was taken place at different times and was conducted in two other schools. Therefore, the characteristics of the research participants contrasted (see Table 1). In terms of gender, there were more male students (56%) in the experimental group, and the control group had a higher proportion of female students (69%). In terms of their teaching careers, the control group had 1–5 years of teaching experience, while the experimental group showed an even distribution of teachers' teaching careers from 1 to 26 years. Next, the major subject in the experimental group was science (88%)at the secondary school level, and two teachers taught at the elementary level (12%). All the control group participants were found to be elementary teachers. (Most elementary teachers in Korea oversee one class, and one teacher teaches all subjects in the class.) In terms of the school level, the control group participants all taught elementary school, while the experimental group was distributed evenly between elementary school (31%), middle school (44%), and high school (25%).
The amount of programming experience appeared to be similar in the two groups. In the control group, four teachers had experience with programming (25%),while half of the experimental group (50%) had such experience. In the control group, three teachers had knowledge of block-based programming languages and one teacher was familiar with text-based programming languages; in the experimental group, six teachers had experience with block-based programming languages, and two teachers were familiar with text-based programming languages. Those who had used a block-based programming language were familiar with Scratch and Entry, while those who had used a text-based programming language had knowledge of C and HTML. The teachers had mainly been exposed to programming via programming-related training. However, some teachers had engaged in programming because of individual interest rather than training. Some of the elementary school teachers reported that they used the programming language to conduct their classes.

Table 1: Characteristics of participants in study

Gender			
Group	Male	Female	Total
Con.	5(31)	11(69)	16(100)
Exp.	9(56)	7(44)	16(100)

Teaching career						
Group	1~5	6~10	11~15	16~20	Over 21	Total
Con.	16(100)	0(0)	0(0)	0(0)	0(0)	16(100)
Exp.	4(25)	4(25)	4(25)	3(19)	1(6)	16(100)

Major			
Group	Primary	Science	Total
Con.	16(100)	0(0)	16(100)
Exp.	2(12)	14(88)	16(100)

School level				
Group	Elementary school	Middle school	High school	Total
Con.	16(100)	0(0)	0(0)	16(100)
Exp.	5(31)	7(44)	4(25)	16(100)

Experience of Programming			
Group	Yes	No	Total
Con.	4(25)	12(75)	16(100)
Exp.	8(50)	8(50)	16(100)

*Con.: Control group, Exp.: Experimental group

3.3 Treatments

In this study, the treatments for the experimental and control groups were based on Kim and Lee's (2017) TPACK-P education model and program, which consists of Analysis–Investigation–Design–Application–Evaluation. Here, in the analysis stage, trainees analyze the problem of the subject; in the investigation stage, they examine the programming development environment, TPACK, curriculum, and examples of TPACK class. Following this, in the design stage, they design a programming class, and they apply the design in a real class in the application stage. Finally, in the evaluation stage, peer review, evaluation, and class reflection are carried out [11].

In this study, it was difficult to schedule the class during the vacation period, when the students did not come to school. Therefore, the participants explained to the peer teachers in the class that the contents of instructional material via peer review and evaluation. In addition, investigation of the curriculum was conducted to analyze the curriculum guidance for preservice teachers, but the teachers already had expertise in understanding the curriculum. Therefore, a curriculum content search for using ICT or programming tools for each subject was conducted. In addition, a search on the programming development environment was conducted for only the experimental group, while the control group was taught about the ICT tool.

The experimental treatment of the control group was carried out on October 4–7, 2016. The lecture time comprised 4 hours each day, for a total of 15 hours, and the TPACK-P training program with no programming elements was applied. The experimental group training was conducted on January 3–7, 2017. The lecture time was the same as for the control group. Some modifications were made to the TPACK-P educational program for the experimental group (see Table 2); this development was based on Baran and Uygun's (2016)studyand incorporated designed-based learning (DBL), a successful teaching method for instructors [24]. Moreover, this study differed from the existing research in that it introduced a programming element called "Scratch" in the experimental group. For the control group, ICT tools like Zoomit, Excel, and PowerPoint were introduced in the classes [11]. Therefore, it can be confirmed that the technological tools were extended in the existing TPACK program.

Table 2: Contents of the TPACK educational program by group

Domain	Content of TPACK educational program	
	Control group	Experimental group
Analysis	Analysis of problem in subject	Analysis of problem in subject
Investigation	Investigation of ICT tools	Investigation of programming environment
	Investigation of TPACK	Investigation of TPACK
	Investigation of example of TPACK Class	Investigation of example of TPACK Class
	Investigation of curriculum	Investigation of curriculum based on programming
Design	Design of class with TPACK	Design of class with TPACK-P
Application	Explain the class	
Evaluation	Instructional criticism	
	Elaboration of class &Feedback	

3.4 Test Tools

In this study, the TPACK-P education program developed by Kim and Lee (2017) was applied to teachers [11]. Therefore, this study used the same test tools as those employed in previous studies, which were based on the TPACK test tool developed by Park and Kang (2014) [12]. As TPACK studies have been actively developed, various testing tools have been generated to measure teachers' TPACK. However, a test tool had not been created for Korean teachers, and the test tools developed abroad did not reflect Korea's cultural background. Therefore, it was necessary to create and validate a test tool that addressed these issues (Helms, 1992) [25]. To accomplish this, Park and Kang (2014) conducted the validation process for adapting the TPACK test tool developed by Chai et al. (2013) to Korean teachers [13]. This test tool originally consisted of 41 items under seven domains; however, through the validation process, a test tool composed of 36 items with a 5-point scale was developed. The items can be broken down into their domains as follows: PK: 7 items, Content

Knowledge (CK): 4 items, TK: 4 items, PCK: 6 items, TPK: 6 items, TCK: 3 items, and TPACK: 6 items. Since the test time of the test tool was not clearly defined, it was confirmed that it was most appropriate when the pilot test was conducted for 15 minutes. Therefore, in adopting the revised tool, a 15-minute offline survey was conducted in the present research.

3.5 Analysis

In this study, the effects of the TPACK educational training with programming on teachers' TPACK were examined. The program was administered to two groups of teachers, and the difference in teachers' TPACK was analyzed before and after training according to the experimental factor(programming). Thus, the pre- and post-tests of the two groups were analyzed through the educational program using a paired-sample *t*-test. To compare the differences between the groups, the results were analyzed using an independent-sample *t*-test.

4. Results and Discussion

4.1 Pre-Test Comparison of TPACK between the Control and Experimental Groups

Prior to applying the TPACK training program, an independent-sample *t*-test was conducted to determine whether there was a TPACK difference between the groups. As a result, the TPACK of the control group (mean [M] = 3.412, standard deviation [SD] = .614) and experimental group (M = 3.526, SD = .347) showed no statistically significant difference, $t = –.540$, $p = .593$. Specifically, there was no statistically significant difference in PK(t= –.670, p= .508), TK(t= –1.861, p= .073), CK(t= –1.483, p= .149), PCK(t= –.903, p= .374), TCK(t= –.228, p= .821), TPK(t= .034, p= 973), or TPACK(t= –.651, p= .520). It was confirmed that there was no difference in the TPACK between the two groups in the pre-test. The TPACK of the teachers in the pre-test is shown in Table 3.

Table 3: The result of in-service teachers' TPACK in pre-test

		Group	*N*	*M*	*SD*	*t*	*p*
Sub-Domain	PK	con.	16	3.688	.562	.670	.508
		exp.	16	3.777	.349		
	TK	con.	16	3.391	.811	-1.861	.073
		exp.	16	3.234	.461		
	CK	con.	16	3.453	.697	-1.483	.149
		exp.	16	3.828	.405		
	PCK	con.	16	3.448	.677	-.903	.374
		exp.	16	3.728	.333		
	TCK	con.	16	3.104	.892	-.228	.821
		exp.	16	3.332	.471		
	TPK	con.	16	3.323	.714	.034	.973
		exp.	16	3.376	.588		
	TPACK	con.	16	3.281	.866	-.651	.520
		exp.	16	3.272	.696		
Total		con.	16	3.412	.614	-.540	.593
		exp.	16	3.526	.347		

4.2. Analysis of the Pre- and Post-Test Change in the Teachers' TPACK in the Control Group

The control group showed improved TPACK in the post test (M = 3.916, SD = .574) compared with the pre-test (M = 3.412, SD = .614). In addition, this change was statistically significant, $t = –2.339$, $p = .034$. Thus, it was confirmed that the TPACK education program with the general ICT tool is effective in improving teachers' TPACK. In the subdomains, statistically significant improvements were observed in the PK ($t = –2.410$, $p = .029$), TPK ($t = –2.566$, $p = .022$), and TPACK ($t = –2.749$, $p = .015$). In contrast, TK(t= –.965, p= .350), CK(t= –1.724, p= .105), PCK(t= -1.849, p= .084), and TCK(t= –1.579, p= .135) increased in the post-test compared with the pre-test, but the change was not statistically significant. Therefore, although the TPACK educational program based on ICT tools affected the teachers' TPACK, it was confirmed that it only affected some of the specific areas as shown in Table 4

Table 4: Change of TPACK of in-service teachers in control group

		test	*N*	*M*	*SD*	*t*	*p*
Sub-Domain	PK	Pre	16	3.688	.562	-2.410	.029*
		Post		4.106	.445		
	TK	Pre	16	3.391	.811	-.965	.350
		Post		3.656	.741		
	CK	Pre	16	3.453	.697	-1.724	.105
		Post		3.922	.675		
	PCK	Pre	16	3.448	.677	-1.849	.084
		Post		3.906	.632		
	TCK	Pre	16	3.104	.892	-1.579	.135
		Post		3.646	.924		
	TPK	Pre	16	3.323	.714	-2.566	.022*
		Post		3.959	.693		

	TPACK	Pre	16	3.281	.866	-2.749	.015*
		Post		3.969	.621		
Total		Pre	16	3.412	.614	-2.339	.034*
		Post		3.916	.574		

*p<.05

4.3 Analysis of the Pre- and Post-Test Change in the Teachers' TPACK in the Experimental Group

In the experimental group, the teachers' TPACK improved in the post-test (M = 3.915, SD = .464) compared with the pre-test (M = 3.526, SD = .347). In addition, these changes were statistically significant, *t* = –2.412, *p* = .029. This result showed that the TPACK with programming education program is effective for improving teachers' TPACK. In the specific domains, statistically significant changes were observed in TK(*t*= –2.440, *p*= .028), TCK(*t*= –2.347, *p*= .033), TPK(*t*= –2.801, *p*= .013), and TPACK(*t*= –2.756, *p*= .015). However, there was no statistically significant improvement in PK (*t*= –1.942, *p* = .071), CK (*t*= –.936, *p* = .364),or PCK (*t*= –1.028, *p* = .320), as shown in Table 5. Therefore, it was confirmed that the TPACK-P education program did not lead to improvements in all areas of teachers' TPACK.

Table 5: Change of TPACK of in-service teachers in experimental group

		test	N	M	SD	t	p
Sub-Domain	PK	Pre	16	3.777	.349	-1.942	.071
		Post		4.107	.507		
	TK	Pre	16	3.234	.461	-2.440	.028*
		Post		3.703	.737		
	CK	Pre	16	3.828	.405	-.936	.364
		Post		4.000	.577		
	PCK	Pre	16	3.728	.333	-1.028	.320
		Post		3.896	.498		
	TCK	Pre	16	3.332	.471	-2.347	.033*
		Post		3.771	.554		
	TPK	Pre	16	3.376	.588	-2.801	.013*
		Post		3.917	.479		
	TPACK	Pre	16	3.272	.696	-2.756	.015*
		Post		3.865	.436		
Total		Pre	16	3.526	.347	-2.412	.029*
		Post		3.915	.464		

*p<.05

4.4 Post-Test Comparison of TPACK between the Control and Experimental Groups

The results of the paired-sample *t*-test revealed that the TPACK training program and TPACK-P education program affected the teachers' TPACK change. To verify these changes, the two groups' post-test results were compared. The comparison showed almost no difference between the experimental group (M = 3.915, SD = .464) and control group (M = 3.956, SD = .574) on the post-test, *t* = –.003, *p* = .997. Furthermore, there were no statistically significant differences for the PK(*t* = –.179, *p*= .859), TK(*t* = –.352, *p*= .727), CK(*t*= .051, *p*= .960), PCK(*t* = –.465, *p*= .645), TCK(*t*= .200, *p*= .843), TPK(*t*= .552, *p*= .585), or TPACK(*t*= .191, *p*= .850) in the subdomains. These results indicate that the teachers showed some changes in TPACK in the educational program, but the changes occurred in both groups, as shown in Table 6. In other words, both the TPACK training program and the TPACK-P education program were effective in improving the teachers' TPACK, but there was no difference in the effect of ICT tools and programming languages as technological tools in the TPACK educational program on the teachers' improvement.

Table 6: The result of pre-service teachers' TPACK in post-test

		Group	N	M	SD	t	p
Sub-Domain	PK	con.	16	4.106	.445	-.179	.859
		exp.	16	4.107	.507		
	TK	con.	16	3.656	.741	-.352	.727
		exp.	16	3.703	.737		
	CK	con.	16	3.922	.675	.051	.960
		exp.	16	4.000	.577		
	PCK	con.	16	3.906	.632	-.465	.645
		exp.	16	3.896	.498		
	TCK	con.	16	3.646	.924	.200	.843
		exp.	16	3.771	.554		
	TPK	con.	16	3.959	.693	.552	.585
		exp.	16	3.917	.479		
	TPACK	con.	16	3.969	.621	.191	.850

		exp.	16	3.865	.436		
Total		con.	16	3.956	.574	-.003	.997
		exp.	16	3.915	.464		

4.5 Discussion

In this study, the effect of programming languages on teacher TPACK as a technology tool in the TPACK education program was analyzed. In the TPACK training program, both ICT and programming language tools were effective in improving teachers' TPACK. However, the specific areas affected by the tools were different. The TPACK education program based on ICT tools affected the teachers' PK, TPK, and TPACK. In contrast, the programming language–based TPACK training program affected TK, TCK, TPK, and TPACK. Therefore, using the programming language as a tool in the TPACK educational program was found to improve the knowledge related to technology among the specific TPACK areas. The problem in education for introducing the existing technology was a lack of knowledge about technology [26,27]. In this regard, the programming language was found to be more effective for improving technology knowledge than ICT tools were [11]. Therefore, the value of programming language as a tool for promoting technology-based education was confirmed.

The merits of introducing technology into education have been confirmed in various studies. However, it takes a lot of time for teachers to integrate and utilize technology in the classroom [28]. This is because the use of technology is fundamentally influenced by contextual factors, and therefore, it can be changed via various characteristics, such as the subject, theme, student level, background, type of technology, and teacher characteristics [29]. Because general technological tools are developed to perform specific functions, they should be used appropriately in accordance with the educational context. In contrast, programming is not as contextual as any other technological tool; thus, a programming language can be used to create a new program to suit the purpose of the educational context [30]. Therefore, programming is associated with fewer contextual constraints and represents less of a burden for integration and use in class [23]. Programming languages are also more appropriate tools than existing technologies for integration in TPACK [11]. Lee et al. (2018) developed TPACK-P, a learning program based on CT, and applied it to preservice and in-service teachers. The irresults showed that TCK, TPK and TPACK were effective in the development of science teachers, but the development of TK was limited. In addition, they found that the development of TK is difficult, even if the technology tools are learned and used for a short period of time [19]. However, in this study, it was confirmed that this problem can be solved if the technological tool is a programming language.

Unlike those using ICT tools, programming-based TPACK training programs are effective for teachers' TK and TCK development. According to previous research, correlations and paths existed among TPACK factors [12,31-34]. Through a model verification of TPACK, Paik (2017) found that for a model in which TK affects TCK and TPK, TCK and TPK affect TPACK. In this study, when the programming language was used as a technological tool for the TPACK education program, it was confirmed that not only TPK, but also TK and TCK, developed [35]. In short, it can be confirmed that the programming language is a more effective tool for teacher TPACK development than the existing tools in TPACK education.

Despite the effectiveness of the programming language–based program, there was no statistically significant difference between the experimental group and the control group in the post-test. It is thought that various factors played a role in this result. First, teaching practice was not conducted. The development of individual knowledge in TPACK has been shown to be limited, since TPACK is an integrated type of knowledge in various [36,37]. Ryu and Lee (2017) confirmed that the experience of teaching practice is effective for TPACK development because it provides dynamic interactions of subdomain knowledge in TPACK [17]. In this study, the teacher explained the designed lesson, and the peer teachers provided feedback and review. Therefore, the lack of experience in teaching practice played a role in the teachers' TPACK development.

The second factor is the nature of programming. It is true that programming is less influenced by the educational context. Since existing text-based programming languages are associated with many difficulties in learning [38-40], this study used a block-based programming language—Scratch—as a technological tool (Ref). However, there were still difficulties in designing a programming-based class [11,16,41]. Such challenges with programming can constrain the development of technology-related knowledge, which is considered to be the reason for the lack of a significant difference between the two groups on the post-test [19,42,43]. Therefore, this result showed that teachers need to learn programming effectively and develop a method of utilizing it in class [11].

Finally, the educational programs had a short duration. The intrinsic purpose of the TPACK education program is to enhance teaching expertise. There are various factors, such as beliefs, attitudes and teachers' knowledge concerning TPACK, that affect teaching expertise. Education requires constant development of these factors. However, in this study, the education program was introduced for only 4 days; therefore, the extent to which these factors could be developed was limited. This can also explain the lack of difference between the groups on the post-test.

5. Conclusion

This study analyzed the effect of programming as a technological tool in a TPACK education program for teachers. Several conclusions can be drawn from the findings. The teachers' TPACK results improved on the post-test compared with the pre-test in the ICT-based TPACK (control) education program. Moreover, statistically significant changes in some specific areas of TPACK were found. In addition, the TPACK-P (experimental) education program affected the TPACK change of the in-service teachers. Through the educational program, the teachers' TPACK improved in the post-test compared with the pre-test. In the specific areas of TPACK, significant improvements were found in TK, TCK, TPK, and TPACK related to technology.

There was no statistically significant difference between the control and experimental groups on the pre- and post-tests. This result showed that the difference in effectiveness of the TPACK training program with the different technological tools was negligible. However, when the changes are considered in detail by group, it can be concluded that programming affected the participants' knowledge about technology. According to previous studies, the development of technology-related knowledge is deeply related to the development of TPACK. Therefore, programming is more effective than ICT tools are for practical TPACK enhancement. This is because, although programming is not a context-neutral tool, it is less influenced by contextual factors. Thus, it was confirmed that there is potential for using programming as a tool for solving the problems raised in various studies concerning integrating technology into education.

In this study, the program treatment had some limitations. The study was conducted for teachers, but there were no students at the school because the training was conducted during the vacation period. Therefore, the TPACK-P education program could not involve real instruction in class, and this was replaced by class explanation and review. As a result, the practical improvement associated with TPACK was limited. In future studies, it will be necessary for the teachers participating in the TPACK education program to study the class directly and observe the TPACK changes accordingly .In terms of previous research, many TPACK studies in Korea used a quantitative approach. The present study also quantitatively analyzed the teachers' TPACK changes. However, in TPACK research, it is meaningful not only to observe the knowledge change, but also to truly observe changes in a teacher's teaching expertise. Therefore, it is necessary to conduct qualitative research to analyze the instruction designed by teachers who participated in the TPACK-P education program and what they teach in schools. In this way, TPACK can be measured as the teacher is instructing students, using observation rather than just the self-report method. Teachers are responsible for teaching in schools, but the students are the ones who come to understand the contents of the class and develop their competence. The TPACK training program should not only focus on improving the teaching expertise, but it should also allow scope for the students to analyze what they think about the class. As the teacher's TPACK develops, the form of the class will change, and students' perceptions about the class will also be altered. Thus, it is necessary to examine students' perceptions of the class before and after the TPACK education program. Like PCK research, TPACK studies concentrate specifically on the subject. Unlike in existing research, this study introduced programming as a technological tool. Because programming languages differ in character from existing technological tools, they may be less valid in relation to some questions on the TPACK test. Therefore, it is necessary to develop the related technological items for the existing TPACK test and verify the revised test tool. Finally, the characteristics of the participants in this study were not in perfect agreement. Therefore, it is difficult to generalize the results of the study. Thus, it will be necessary to repeat this research on populations and generalize the results of the TPACK-P education program.

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