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Capacity Building in Technological Pedagogical Content Knowledge for Preservice Teacher

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This study explored the pattern of changes in the "Technological Pedagogical Content Knowledge (TPACK)" of preservice teacher students during practicum as well as methods for analyzing and assessing such changes. It aimed at identifying the terms and environment that would benefit including TPACK in the guidance programs of teaching practice (practicum) for preservice teacher students. This study had three significant findings: 1) If TPACK is deliberately taught in practical instruction, what was previously learned of TPACK in certain forms (lecture, etc.) could be further examined in practice; 2) When giving instruction recognizing the TPACK framework, MindMap can be considered as capable of recognizing TPACK and can be a tool to visualize changes for both instructors and preservice teachers; and 3) If mentioned in the conditions and environment causing transformation, opportunities to encourage visualization of knowledge and thinking are important to both instructors and preservice teachers..

Keywords: preservice teacher education, PCK, TPCK, TPACK, practicum

Introduction

In the Partnership for 21st Century Skills (2004) in the US, it was said that new teachers must be prepared to redesign and create curricula and instruction methods in order to provide their students with the skills of a twenty-first century literate citizen. In the ten years since then, children's learning environments have been increasingly changing. The knowledge and skills required of teachers have changed thereto as well, in accordance. That is, teachers are now expected to have the knowledge and skills for teaching with and about technology in their assigned subject areas and grade levels. Moreover, not only preservice teachers but also in-service teachers are requested to make creative links between what should be learned, how it is taught, and how best to make use of the appropriate tools in the current learning environment. This implies more than simply adding ICT to traditional approaches. It depends upon a deep knowledge of how ICT can be used to access and process subject matter as well as an understanding of how ICT can support and enhance learning in combination with Pedagogical Content Knowledge.

The challenge facing the modern teacher is how to incorporate multimodalities and differentiated educational technologies to facilitate and/or enhance student learning. As a solution, teachers must acquire and develop technological pedagogical content knowledge (Mishra & Koehler, 2006). This framework builds on Shulman's construct of Pedagogical Content Knowledge (Schulman1986, 1987) to include Technological Knowledge.

Theoretical Background and Previous Studies

This study covers the pedagogical content knowledge related to technology called Technological Pedagogical Content Knowledge (originally TPCK, now used in many recent studies as TPACK to refer to the "total package" of technology, pedagogy, and content knowledge). TPACK is a framework that attempts to grasp the relationships between knowledge of teaching, subject matter, and use of technology as well as their compound nature (Mishra & Koehler, 2006). As such, recent educational media and technology research has focused on TPACK (Archambault & Barnett, 2010; Jang, 2010; Jimoyiann, 2010; Kramarsky & Michalsky, 2010).

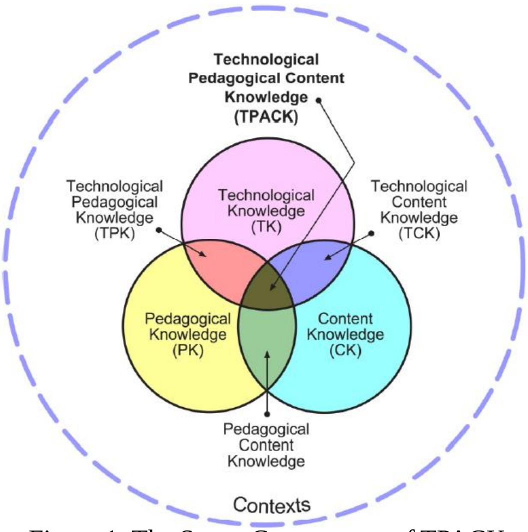

Figure 1. The Seven Components of TPACK
(http://www.matt-koehler.com/tpack/tpack-explained/)

In TPACK, teacher knowledge for technology integration makes the learning effective and efficient. Technology integration is considered a closely related component of effective teaching and is included in PCK. Particularly in preservice teacher education, the importance of cultivating "Pedagogical Content Knowledge (PCK)" has been emphasized. For teachers to have an image of learning, including the use of information and communication technology (ICT), in addition to "Technological Knowledge (TK)," such matters as development and training must be approached through "Technological Pedagogical Knowledge (TPK)," "Technological Content Knowledge (TCK)," and "Technological Pedagogical Content Knowledge (TPCK)."

Figure 1 shows the close relation of TPACK, TCK, and TPK with PCK. TPACK, TCK, and TPK are shown as three potential abilities and additional components of PCK (Koehler & Mishra, 2009).

However, TPACK elements overlap in actual teacher professional development and training. Demands to clarify the definition and framework had been made as these overlapping elements render difficulty in understanding. Schmidt, Baran, Thompson, Mishra and Koehler (2009) pursued this framework through further investigation on TPACK as regards perception of preservice teacher students in the development process of said framework. Voogt, Fisser, Pareja, Tondeur, and Braak (2013) and Chai, Koh, and Tsai (2013) provided recent information on previous TPACK research.

Some trends are evident in the previous research on TPACK (see Figure 2). For example, if the number of papers is taken into account, it seems that many more studies on the preservice teacher education than the in-service teacher education are found to exist. In terms of subjects, many studies on science and mathematics can be found. Among them, looking at the preservice teacher education research that targets science, two trends are observable. One trend involves research into preservice teacher students in the development stage and their instructional knowledge and ability (Angeli & Valanidies, 2009; Chai, Koh, & Tsai, 2010; Kramarsky & Michalsky, 2010; Niess, 2005). The other concerns preservice teacher student perception of the university teacher's TPACK related instructional ability (Jang & Chen, 2010; Tuan, Chang, Wang, & Treagust, 2000). However, these studies often use some questionnaires and pay attention to the awareness and consciousness survey regarding TPACK.

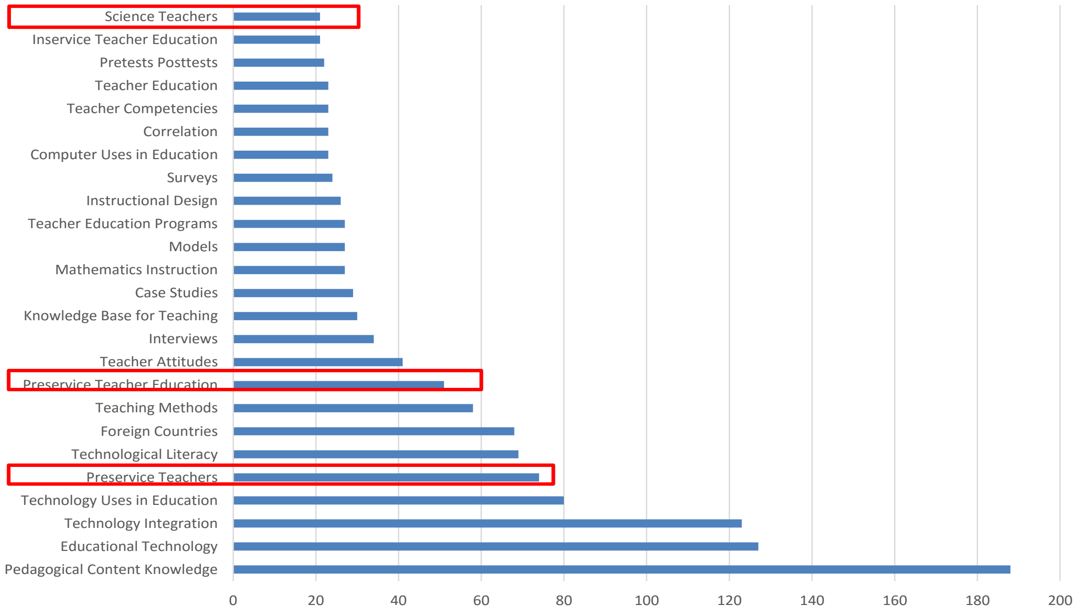

Figure 2. 2006–2015 TPACK studies from the ERIC database, July 2015

Research Aims and Research Questions

Practicum in science classrooms at Japanese schools has since focused on what materials to use, what to teach the students, what abilities to impart, and what practical skills to instill to enable educational planning preparation. Another focus is the implementation suited to the students' actual situations. Recently, teachers have been required to improve students' learning skills through ICT, which has been part of the framework for 21st century learning. As such, the provision of instruction tailored to individual preservice teachers, paying attention to skills for goal-oriented use of ICT in a limited timeframe, has become an issue.

To respond to these issues, the present study explores a multitude of ideas on what preservice teacher students need to learn while gaining TPACK. For instances, the present study pays attention to preservice teacher's cognition regarding TPACK through performance, rather than identifies preservice teacher's consciousness and awareness of TPACK though questionnaire. It considers how preservice preparation programs should arrange to ensure that preservice teacher students gain methods of knowledge and thinking associated with TPACK.

Considering the earlier studies described above and the preservice preparation program of TPACK in teacher education, the following research questions were formulated:

1. What kind of action and performance do preservice teacher students show in practicum that target the science after the instruction regarding TPACK ?
2. What types of TPACK knowledge do preservice teacher students recognize in practicum that target the science after the instruction regarding TPACK ?
3. Is there an effective analysis method to understand the changes in the TPACK which preservice teacher students have acquired in practicum that target the science?

Through preliminary research, the present study attempt to unveil different types of phenomenon (action and performance), background knowledge, and experience of preservice teachers that affect their learning of TPACK. Then, through secondary research, it attempts to clarify the types of TPACK knowledge that were thought as factors to transformation by analyzing preservice teachers' cognition with MindMap.

Research Design and Method

As preliminary research, the present study looked into the TPACK training program for a period of over two years at the Graduate School of Education. Participants of the study included two male graduate students in the first year and four graduate students (one male and three females) in the subsequent year (see Table 1).

After lectures on TPACK framework, innovative teaching and learning concept, and ways to integrate ICT into subject learning, the graduate students began their practicums at primary or secondary schools. Observation data recorded on video and data from interviews with graduate students, mentor teachers, principals, and university supervisors were collected through lesson study during teaching practice (practicum). Four people, namely, the graduate student, mentor teacher, principal, and researcher, carried out discussions of each scene over the lesson record whenever one lesson ended. Records of the reflection and discussion were transcribed as text data and analyzed using the text record, photographs, and video record.

Table 1.
Participants of a preliminary research

	Project year	Participant	school	subject	TPCK Framework	ITL Concept	ICT use
A	2011	Male (35),Major ;Japanese,Minor; education	Senior high,2 grade	Japanese	attend	attend	attend
B	2011	Male (24),Major ;education,Minor; science	primary,5 grade	science	attend	attend	attend
C	2012	Male (27),Major ;math,Minor; education	Junior high,2 grade	Math	attend	attend	attend
D	2012	Female (24),Major ;education,Minor; math	primary,5 grade	Math	attend	attend	attend
E	2012	Female ,Major ;education,Minor; math	Junior high,1 grade	Math	attend	attend	attend
F	2012	Female (24),Major ;science,Minor; education	primary,5 grade	science	attend	attend	attend

This paper focused on preservice teachers B and F. We analyzed their data because of their similar situations and practicum that target science. Through preliminary research, the present study attempted to unveil different types of phenomenon (action and performance), background knowledge, and experience of preservice teachers that affects their learning of TPACK. However, in this way, it was difficult for us to clarify “what action was associated with what TPACK knowledge.” We also needed to investigate how the case of junior high schools is different from the case of primary schools. Then we began to plan the second research.

The purpose of the second research in 2014 was to explore changes in the TPACK of preservice teacher students (undergraduate) during practicum by using MindMap. Mentor teachers have had information on TPACK instruction and rich experiences in science lesson preparation using ICT. This study aimed at determining the terms and environment that would benefit from having TPACK in the guidance programs for preservice teacher students. Advocated by Tony Buzan, a MindMap is a thinking tool that enables visualization of what one is thinking and illustrates the widening of thoughts on a certain theme in a layered form. The theme is expressed as a central image. From the theme, a branch widens in a radial fashion. The first branch is called the main branch (first level) and basic ideas are entered as keywords above this branch. Associations are further widened by developing second and third levels and sub branches.

Accordingly, MindMap was used as a tool to grasp changes in what is considered important and the extent to which deep thought is possible. MindMaps were created before and after the practicum of the preservice teachers for them to understand their own growth through self-comparison. The preservice teacher’s cohort made group MindMaps on the topics of their choice with the intention of deepening discussions toward problem solving of science lessons. Further, the researchers loaned out iPads (iMindMap HD, a mindmap drawing software) for situational awareness using ICT to make class observation more efficient and progress in educational critique meetings smoother.

In the MindMap, associated words are linked as the preservice teachers repeat questions going from the main branch, which is connected to the central image, to the sub-branch. By tracing words along branches of the MindMap, we (three mentor teachers and one university researcher) can thereby estimate the context in which the words of each branch were written, by referring to Figure 1 and the TPACK definition (Matthew, Koehler and Mishra 2015). By using this, it was considered possible to estimate the type of TPACK model knowledge used in the thought process that resulted in the rope branch.

Figure 3 is part of the MindMap made by a preservice teacher. By focusing on the top series of branches and lining up words in order from the main branch to the tips of the sub branches, the result is (1) circuit → (2) electric current course →(3) cathode to anode. The flow of thought estimated from this arrangement is "Speaking of circuits → a path for electric current → How does electric current flow? → From cathodes to anodes." Since these are the details of so-called scientific learning, among the components of TPACK, they are conceived as falling under CK. Then this series of branches was counted as one branch including CK. Since the remaining two branches in the same fashion include CK, the basic idea of the image can be said to have a total of three branches including CK in the circuit main branch.

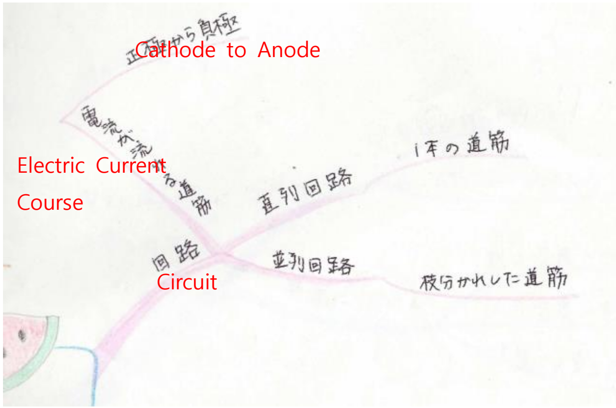

Figure 3 The MindMap made by Preservice Teacher

In order to improve the reliability of analysis, the three instructors (mentor teachers) who managed the preservice teachers in this instance discussed the subjectively viewed actual conditions of the preservice teachers along with the statements on the MindMap, while forming a consensus to classify what components of TPACK they fall under.

Based upon these procedures, transformations in the preservice teachers were analyzed by classifying, quantifying, and comparing branches of MindMap prepared at the beginning of educational practical training classes with those prepared after the practical training..

Results

Results through a preliminary research were identified by comparing two participants in a similar situation. We prepared for Content test (the weather and the movement of cloud which he teaches during practicum), ICT test (WWW, Picture and Video editing, PowerPoint etc.) and Description test regarding the significance and the method of using ICT in the classroom. We tried to identify different types of phenomenon (action and performance during practicum), background knowledge, and experience of preservice teachers that affects their learning of TPACK.

The first case was a male student in 2011 (Preservice teacher B in Table 1). The participant had confidence in Content Knowledge (CK), Technological Knowledge (TK), and Pedagogical Knowledge (PK) (refer to Table 2). He used ICT positively in his lessons from the beginning. He used ICT appropriately in the teaching and learning contexts after the mentor's guidance for a short period. His behavior was attributed to his awareness of new pedagogy concepts and the close attention paid by him to students during learning activities.

Table 2
The result of Pre-test of Content, ICT, PK in a preliminary research

	Content test	ICT test	PK desctiption
Student B	90	90	Focus on Teaching and Learning by using ICT
Student F	95	60	Focus on Teaching by using ICT

The second case is a female student in 2012 (Preservice teacher F in Table 1). She had confidence in Content Knowledge (CK) and Pedagogical Knowledge (PK). She was not good at ICT and did not have confidence in Technological Knowledge (TK) (refer to Table 2). However, she was able to use ICT effectively in the teaching context after the mentor's guidance over a short period. Further, she spent a long time using ICT effectively for her presentation and explanation. It seemed difficult for her to use ICT for children's learning activities. This was attributed to her attention to teaching the ICT subject.

Table 3
The summary of results of Pre and Post MindMap

	Pre N	Post N	Pre M	Post M	Pre SD	Post SD
CK	214	156	16.46	12	16.37	8.1955
PK	69	87	5.308	6.692	6.848	6.3428
TK	1	0	0.077	0		0
PCK	37	210	2.846	16.15	3.436	9.1819
TPK	1	1	0.077	0.077	0.277	0.2774
TCK	3	0	0.231	0	0.832	0
TPCK	4	11	0.308	0.846	1.109	1.4051

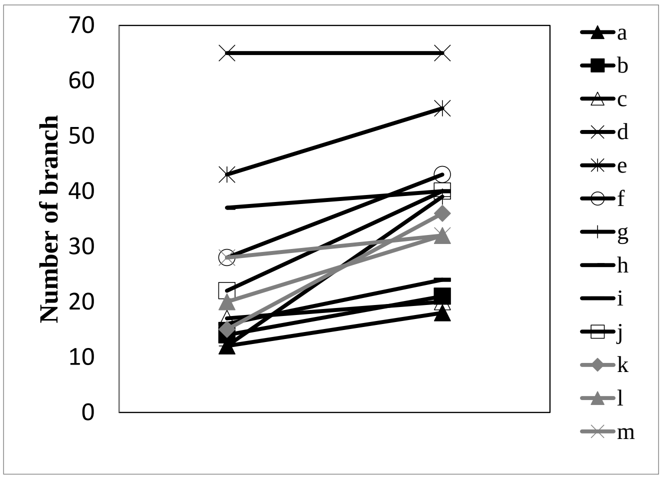

Figure 4. Result of Pre and Post MindMaps by Students

The results of the two case studies in a preliminary research demonstrate two things. First, the results showed no significant difference even when a preservice teacher had limited TK and experience of ICT utilization before practicum. The cases indicated the possibility of integrating a TPACK Program into the practicum. Second, both cases highlighted the importance of considering the view of pedagogical knowledge (PK) to improve TPACK. Moreover, changes were observed in the mentor teachers and principal who participated in the project. At the beginning, the mentor teachers and principal were guiding the preservice teacher students based on their idea of the lessons (PK and PCK) drawn from their own previous experiences. Their comments often focused on using ICT effectively as the subject teaching method and tool. However, changes were visible as they continued to participate in lesson study. The point of emphasis in guidance changed from using ICT for effective teaching to using of ICT effectively in students' individual learning activities. Hence, when designing the integration of TPACK program into the practicum, mentor teachers need to possess a thorough understanding of TPACK as well. Through secondary research, Table 3 and Figure 4 present the summary of results of individual pre and post MindMaps made by preservice teacher students.

Table 4 and Figure 5 use the results of classification by TPACK components of MindMap branches. There were types of pre MindMap where branches including CK predominate; this type includes preservice teachers a, b, c, d, g, h, j, k, l, and m. Another type is the one where branches including PK predominate as in those of preservice teachers e, f, and i. These results indicated a separation between two types; one involved preservice teachers with a strong awareness of the details of scientific knowledge before teaching practical training, whereas the other set had a strong awareness of teaching method. In classes in the beginning of practical training, there were cases in which the details of science were taught according to the best of the teacher's ability. Meanwhile, there were classes leaning heavily on explanation or those in which learning was not deep even though the teaching method followed the procedures, as few scientific details were present. This is in line with the realization of practical training instruction that instructors had at the time.

Table 4

The results of classification by TPACK components of MindMap branches by students

	Student a		Student b		Student c		Student d		Student e		Student f		Student g		Student h		Student i		Student j		Student k		Student l		Student m	
pre/post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
CK	7	2	8	6	9	13	62	29	14	6	3	13	11	7	36	11	1	12	22	0	9	22	17	20	15	15
PK	2	3	5	6	4	1	2	13	16	15	21	18	0	1	0	14	13	6	0	8	3	0	2	0	1	2
TK	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PCK	3	13	0	9	4	5	1	23	13	29	4	12	1	30	1	14	2	6	0	32	2	13	1	11	5	13
TPK	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
TCK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
TPCK	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	1	0	0	0	0	0	1	0	1	4	2
Sum	12	18	14	21	17	20	65	65	43	55	28	43	12	39	37	40	16	24	22	40	15	36	20	32	28	32

Comparing pre and post MindMaps, results showed significant differences among individuals and increased number of branches including PCK among all preservice teachers (see Figure 5 and Figure 6). These results could be considered to be the outcome of a transition from one's previous inability to the acquired ability to think before and after practical training. One's inability to think makes him/her link teaching methods to the details of scientific learning that must be taught before practical training (practicum). Meanwhile, one's ability to think allows him/her to link how to teach the details of scientific learning after practical training (practicum).

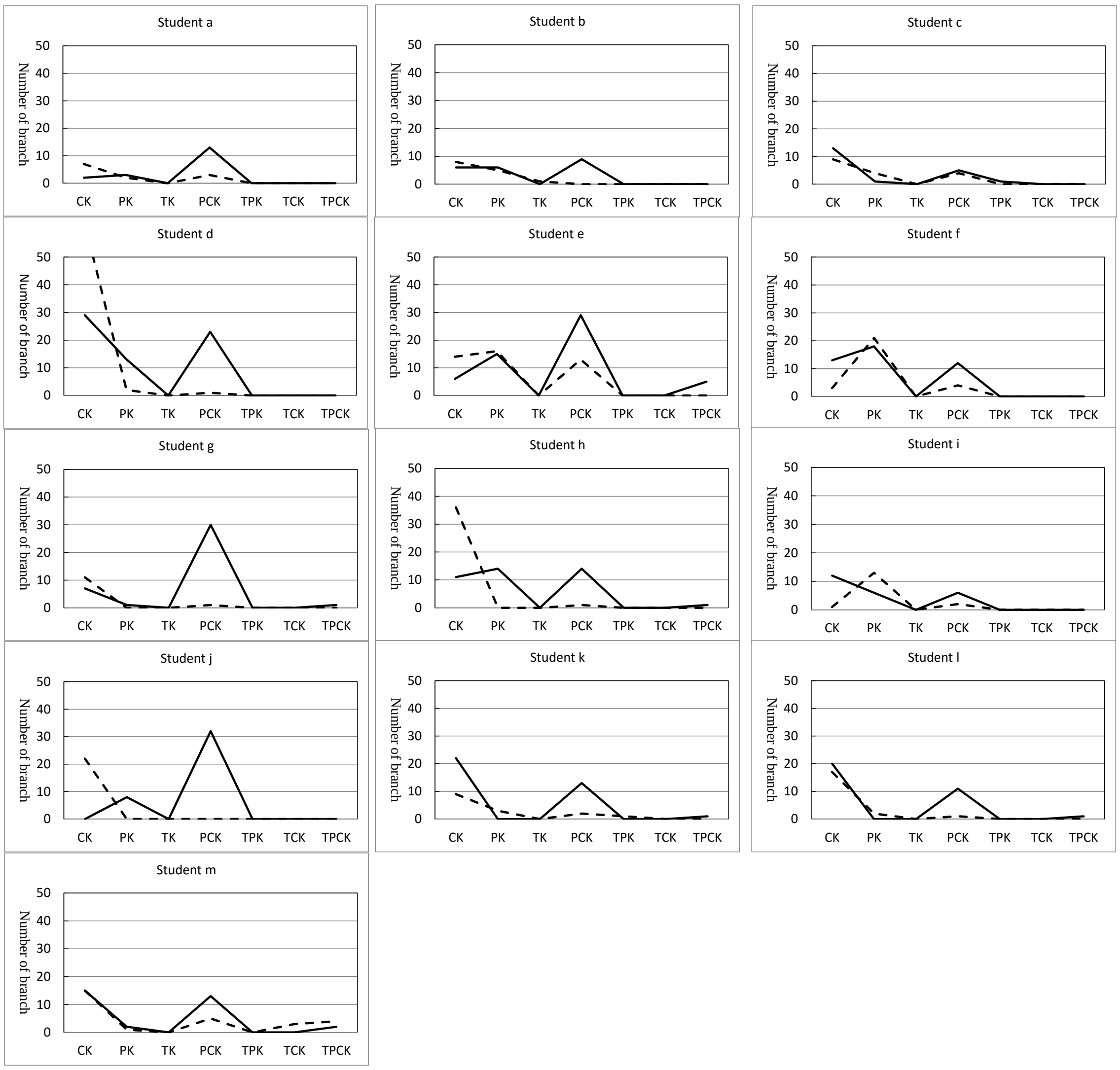

Figure 5. Number of branches of TPACK by student

From such a result, when we consider the TPACK of preservice teachers, it was expected that PCK was an important key. The researchers analyzed the correlation of the increase in number of branches regarding PCK with preservice teacher students' practical ability by using their evaluations conducted by instructors (mentor teachers) (see Figure 6 and Figure 7).

Evaluation of preservice teachers at the school was conducted by an overall score of a ten-stage evaluation of a variety of items in practical instruction as regards teaching subjects. From the evaluation items, we extracted the status of educational materials research, instructional plan drafting, development of the lesson and instructional technology along with the use of questioning, writing on whiteboards, teaching tools, and teaching materials and texts. All of these items are directly related to teaching. Total scores were analyzed. A positive correlation was seen between the instructor evaluation of preservice teachers and the number of branches regarding PCK in the post mind map. Additional examination was conducted using the Spearman rank order correlation coefficient. Due to the examination results, a positive correlation was inferred between the instructor evaluation of preservice teachers and the number of branches regarding PCK in the post MindMap ($R2 = 0.57$, $p < 0.05$). The results of the analysis using the MindMap of PCK transformations indicated that the MindMap assists in understanding the changes in the practical ability of preservice teachers.

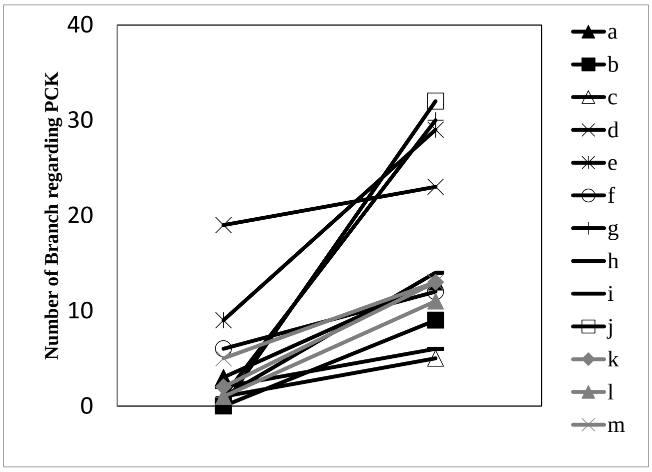

Figure 6. Result of Pre and Post MindMaps regarding PCK by Students

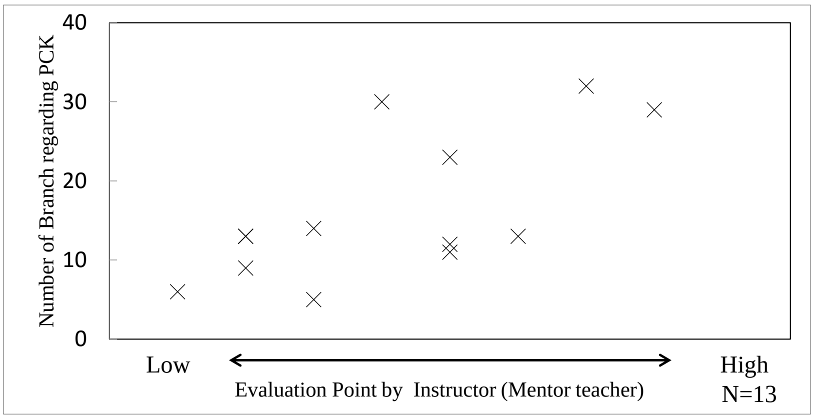

Figure 7 the correlation of the increase in number of branches regarding PCK with evaluations conducted by instructors

Branches including TCK, TPK, and TPACK were detected in preservice teachers b, c, e, g, h, k, l, and m. These branches also tended to increase in the post MindMap compared with the pre MindMap. In practical application, all preservice teachers observed or implemented classes using document cameras, electronic blackboards, and iPads. However, branches including TCK, TPK, and TPACK could not be detected in MindMap for all pre service teachers. As such, student teacher “e” taught how to use gas burners in the final class while confirming it with a document camera. Student teacher “g” in the final class used a document camera to teach a calculation method with which the students had difficulty in a relatively easy manner. Student teacher “h” showed an actual item with a document camera to arouse interest among students in the final class. Since the subject of the last class was the human body, preservice teachers from “k” to “m” used a large amount of images as teaching materials. The results strongly depended on the details of the final class. However, a trend showed that the number of branches including TPACK tend to increase in post MindMap. If this trend is observed to be linked to PCK increase, changes must be made to enable consideration of how and for what purpose to use ICT among preservice teachers who are thinking about how to teach science. We think that the results may be best understood as perceptual through performance rather than performative, since this research interest did not pay attention to the change of teaching behavior(s).

Findings

Below is the summary of findings of the study.

1) An instruction recognizing the TPACK framework for ICT use in the practical instruction class preparation cycle is found to exist. As a result, more branches including TCK, TPK, and TPACK were detected in post rather than pre MindMap (refer to Figure 8 and Figure 9).

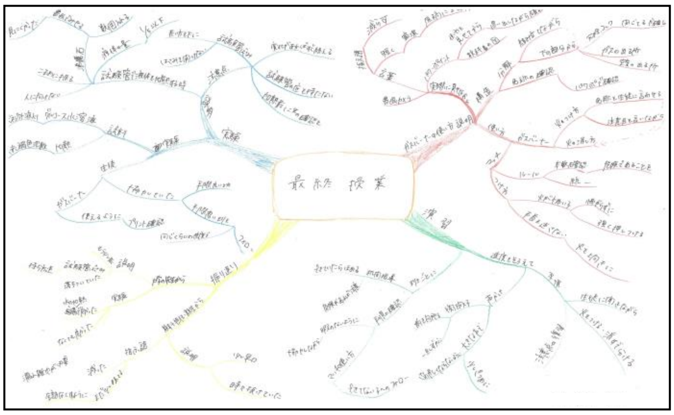

Figure 9. Post MindMap by preservice teacher student

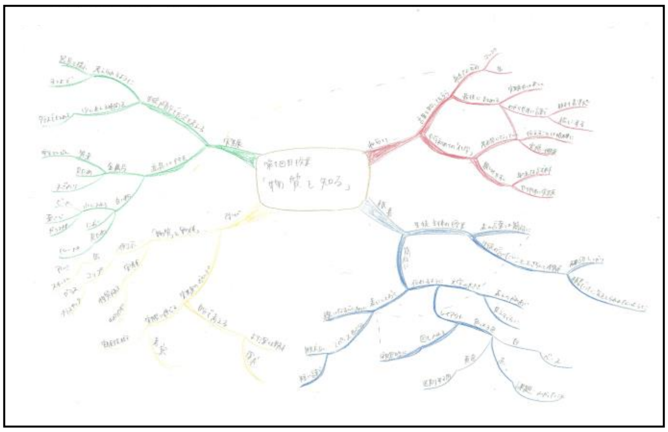

Figure 8. Pre MindMap by preservice teacher student

However, many changes are seen in PCK as the overall process of knowledge transformation was examined, as illustrated in Figure 5. Since the preservice teachers were affected by such factors as the purpose and details of the managed classes, it was understood that finding TK, TCK, and TPK independently would be difficult. (The researchers found difficulty in becoming aware of the use of such knowledge). When TK, TCK, and TPK appear, they do so in the form of a mixed TPACK. Moreover, as preservice teacher student "m" indicated, even if there is greater awareness of TCK, TPK, and TPACK at the time of the pre MindMap, transformation that can enable a consideration of when and for what purpose to use ICT was arrived at through a practical experience. Hence, if TPACK is deliberately taught in practical instruction, what was previously learned of TPACK in certain forms (lecture, etc.) was further examined in practice.

2) In MindMap, since words are connected to branches in the order of thinking, tracing words from main branches to sub branches enables reading of the context in which the words appear. Using these characteristics to conduct analysis through the use of mind maps and by quantifying fitting the TPACK components, understanding the transformation of preservice teachers is possible. As such, when giving instruction that recognizes the TPACK framework, the process proved that the MindMap recognizes TPACK and can be a tool to visualize changes for both instructors and pre service teachers.

3) During practicum, the preservice teachers created pre, group, and post mind maps. Creating group MindMap expresses mutual thinking on an image of teaching and is effective in recognizing the required knowledge. If mentioned in the conditions and environment causing transformation, opportunities through such groups to encourage visualization of knowledge and thinking are important. Results of using

MindMap to understand changes in preservice teachers will be reflected in the future in the formative evaluation and instruction of preservice teacher students.

Conclusion

This study explored the changes in the "Technological Pedagogical Content Knowledge (TPACK)" of preservice teacher students during practicum as well as methods for analyzing and assessing such changes. In addition, we have provided details of some of our recently published papers that we believe have made significant contributions to existing knowledge.

The main contribution of this paper is its use of the technological tool MindMap to analyze the types of changes that have been made to the set of knowledge and skills for science pre-service teachers. We believe that this contribution is theoretically and practically relevant because of its insights that are useful for program preparation.

This study is of particular interest and use to educators and scholars in the education field, especially in the area of science education. Further, we believe that the above three findings match the aims of capacity building in "Technological Pedagogical Content Knowledge" for preservice teachers because they highlight the significance of technological tools in improving educational practice.

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