MEASURING COMPETENCES OF PRE-SERVICE SCIENCE TEACHERS' TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

Mehmet Fatih Taşar, Betül Timur

ABSTRACT
The turn of the 21st century marked the beginning of a much common and widespread use of computer technologies in science classrooms and practically everywhere else because personal computer hardware with ever higher capacities became affordable to larger populations and applications with enhanced visual characteristics were created with lesser effort not only by computer experts but also by science educators. Although not sufficient for all teachers, today there exist many opportunities for both in-service and pre-service science teachers and students to utilize Technology-Rich Environments (TRE) in teaching and learning science. This study aims to measure pre-service science teachers' Technological Pedagogical Content Knowledge (TPCK) confidence and identifying views about using TRE in science instruction. A descriptive multicase study design was employed in order to examine pre-service science teachers' TPCK confidence during a whole semester. Data include semi structured interviews and TPCK confidence survey. The results of the study suggest that pre-service science teachers have not got TPCK confidence enough to create a TRE in science teaching and they feel lack of technological content knowledge competences for creating a TRE.

KEYWORDS
Technology-Rich Environments, Technological Pedagogical Content Knowledge, Pre-Service Science Teachers, Inquiry-Based Learning, Computer Simulations.

INTRODUCTION

The constructivist approach to teaching and learning stresses that learners are not blank slates on which to write freely. Rather they come to the learning environments with all sorts of pre-conceptions and often times these are not scientifically acceptable. Moreover, science teaching is not sufficiently effective in providing meaningful understandings for students. Students continue to subscribe to non-scientific ideas while thinking about the natural phenomena even after instruction on those topics. Science teachers as facilitators of learning in classrooms design meaningful learning activities and environments in which students can gradually construct an understanding compatible with the scientifically acceptable ones.

Science teachers as facilitators of learning in classrooms design meaningful learning activities and environments in which students can gradually construct an understanding compatible with the scientifically acceptable ones. Hence, science instruction should help them:

a. add powerful, durable, and generative examples to their repertoire of ideas; and
b. enable students to grapple with their full repertoire of ideas to form a more coherent perspective on the scientific domain. Technology-enhanced materials that make scientific thinking visible can play an important role in both processes. (Kali & Linn, 2008)

Computers first become visible in schools starting early 1980's and showed a rapid spreading in the subsequent years. In a national survey (Becker, 1986) in the US data were gathered from more than

10,000 elementary and secondary school teachers and principals. The results showed that the number of computers used for instruction was increased from just a couple thousands in spring 1980 to more than 1 million by spring 1985. Since then the use of computers in school instruction has increased progressively and continues to be so even more heavily. This progression was not only in the number of computers being used in schools, but also the way they are being utilized was revolutionized (Keeves & Darmavan, 2009).

Today, interactive computer simulations are main examples of technology-enhanced materials used in science classrooms for almost all science concepts in the K-12 curriculum (Smetana & Bell, 2006). Additionally, they "present dynamic theoretical or simplified models of real-world components, phenomena, or processes, allowing students to observe, explore, recreate, and receive immediate feedback about real objects, phenomena, and processes." Direct access to internet from home, school, and practically everywhere else allows students to explore many free web sites that include astonishing science simulations. TRE offers opportunities to science educators to create natural phenomena which might be difficult or impossible to view, dangerous to conduct, not practical or too expensive to bring in the classroom, or messy or time-consuming to prepare in a school laboratory. However, science teaching cannot and should not be totally done by TRE. Pre-service science teachers need to know how to create TRE in science classrooms and teachers should have special content competencies.

TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPCK)

Technological pedagogical content knowledge (now known as TPCK or TPACK) has become a commonly referenced conceptual framework of teacher knowledge for technology integration within teacher education. TPCK is described as complex interaction of content, pedagogy and technology and discussion of successful integration of technology into instruction (Koehler & Mishra, 2008). In recent years researchers described technological pedagogical content knowledge (TPCK/TPACK) within Schulman's (1987, 1986) framework description of pedagogical content knowledge (PCK). According to Schulman (1986, p.9) PCK "goes beyond the knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" and PCK is the connection and relation of pedagogy and content knowledge.

A precise definition of TPCK in relation to PCK is given as follows:

> [it is] the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones. (Koehler & Mishra, 2009, p. 66)

Another view complements the above definition by emphasizing the intricate inter-relationships:

> [C]ontent, pedagogy, learners, and technology are contributing knowledge bases to TPCK, but knowledge and growth in each contributing knowledge base alone, without any specific instruction targeting exclusively TPCK as a unique body of knowledge, does not imply automatic growth in TPCK. (Angeli & Valanides, 2009, p. 158)

Hence, the relationship between ICT and TPCK is given in a single concept labeled as ICT-TPCK and defined as follows:

> [T]he ways knowledge about tools and their pedagogical affordances, pedagogy, content, learners, and context are synthesized into an understanding of how particular topics that are difficult to be understood by learners, or difficult to be represented by teachers, can be transformed and taught more effectively with ICT, in ways that signify the added value of technology. (Angeli & Valanides, 2009, p. 158-159)

The core of TPCK is that it underlies how teachers understand educational technologies and how their PCK interacts with technology to produce effective teaching/learning environments with technology.

Developing Teachers' TPCK through Professional Development

Recent studies examined the development of TPCK during and through professional development (PD) programs (Guzey & Roehrig, 2009; Graham, Burgoyne, Cantrell, Smith, Clair & Harris, 2009). The findings indicate that PD programs can have positive impacts on both in service and pre-service science teachers' TPCK development.

In another study, Niess (2005) integrated technology in a teacher preparation program and examined 22 pre-service science and mathematics teachers' development of TPCK. The study described "five cases about the difficulties and successes of student teachers teaching with technology in molding their TPCK". Another research about TPCK introduces (Harris, Mishra & Koehler, 2009), TPACK-based learning activity types, which can help teachers successfully, integrate technology into their practice, as an alternative to existing professional development approaches.

On the other hand, a recent paper (Hew & Brush, 2007) identified 123 barriers faced by teachers by reviewing existing empirical studies. They classified these barriers into 6 main categories: (a) resources, (b) knowledge and skills, (c) institution, (d) attitudes and beliefs, (e) assessment, and (f) subject culture. Some recent studies focused on the barriers effecting technology integration such as limited access to internet, classroom size, and lack of teachers' knowledge about successful technology integration into instruction (Çakır & Yıldırım, 2009; Cure & Özdener, 2008; Erdemir, Bakırcı & Eyduran, 2009; Ertemer, 1999, 2005).

AIM OF THE STUDY

The aim of this study is to measure pre-service science teachers' TPCK confidence and to identify their views about creating Technology-Rich Environments (TRE) in science teaching.

RESEARCH QUESTIONS

This study will focus on the following research questions:

1. What is the perceived confidence level of pre-service science teachers' related to the four TPCK constructs? (technological knowledge, technological pedagogical knowledge, technological content knowledge, technological pedagogical content knowledge)
2. Is there any gender difference in the perceived confidence level of pre-service science teachers' related to the four TPCK constructs?
3. What do pre-service science teachers' ratings of their perceived confidence levels related to TPCK say about the framework itself?
4. What are the pre-service science teachers' views about TRE and throughout their education how were their TRE experiences?

PARTICIPANTS OF THE STUDY

The participants of this study are 42 (23 female and 29 male) sophomore pre-service science teachers.

DATA COLLECTION and ANALYSIS

Both quantitative and qualitative research methods were used in this study. In order to determine pre-service science teachers' views about using TRE interviews were conducted with 6 pre-service science teachers. And also TPCK confidence survey was used to measure pre-service science teachers' TPCK confidence. The survey was developed by Graham, Burgoyne, Cantrell, Smith, Clair, and Harris, 2009. Timur and Taşar (2010) adapted the survey. The adapted survey has 4 sub-factors named as first TPK, second TK, third TCK and fourth TPCK. TPK sub-factor consist of 8 items and its cronbach alpha coefficient is .85, TK sub-factor consist of 8 items and its cronbach alpha coefficient is .94, TCK sub-factor consist of 5 items and its cronbach alpha coefficient is .94 and TPCK sub-factor consist of 3 items and its cronbach alpha coefficient is .91. The adapted TPCK science survey has an overall alpha of .96 and 24 total items.

The data were analyzed using the Statistical Package for the Social Sciences and semi-structured interviews with the pre-service science teachers were audio recorded and transcribed verbatim. The aim of the interviews was to collect more detailed data from the participants. The purpose of the interviews was to find out the pre-service science teachers' views, needs, and classroom practices about TRE. Qualitative research must show enough detail for the reader to be able to see the case clearly and so the researcher's conclusion will make sense (Creswell, 1998).

Table 1. Survey items with sub-factors

Sub-factors	**ITEMS**
TPCK	1. Use digital technologies to facilitate scientific inquiry in the classroom. 2. Help students use digital technologies to collect scientific data. 3. Help students use digital technologies to organize and identify patterns in scientific data.
TPK	4. Help students use digital technologies that extend their ability to observe scientific phenomenon. 5. Help students use digital technologies that allow them to create and/or manipulate models of scientific phenomenon 6. Use digital technologies to improve my teaching productivity 7. Use digital technologies to improve communication with students. 8. Use digital technologies to motivate learners. 9. Use digital technologies to improve the presentation of information to learners. 10. Use digital technologies to actively engage students in learning. 11. Use digital technologies to help in assessing student learning.
TCK	12. Use digital technologies that allow scientists to observe things that would otherwise be ficult to observe. 13. Use digital technologies that allow scientists to speed up or slow down the representation of natural events. 14. Use digital technologies that allow scientists to create and manipulate models of scientific phenomenon. 15. Use digital technologies that allow scientists to record data that would otherwise be difficult to gather. 16. Use digital technologies that allow scientists to organize and see patterns in their data that would otherwise be hard to see.
TK	17. Save an image from a website to the hard drive of your computer. 18. Search the web to find current information on a topic that you need. 19. Send an email with an attachment. 20. Create a basic presentation using PowerPoint or a similar program. 21. Take and edit a digital photograph. 22. Create and edit a video clip. 23. Use Web 2.0 technologies (e.g., blogs, social networking, podcasts, etc.). 24. Create your own website.

RESULTS AND DISCUSSION

Perceived confidence levels

To address the question of perceived confidence levels related to the four TPCK constructs the participants were asked how they would rate their confidence related to the associated task. Means were calculated for all items and are shown in table 3 and average scores for four sub-factors are shown in table 4. The value ranges of the 5 point Likert type confidence scale are shown in table 2.

Table 2. The Ranges Belonging Confidence for Likert Type Scale

Value Range	Confidence
1.00–1.79	not confident at all
1.80–2.59	slightly confident
2.60–3.39	somewhat confident
3.40–4.19	fairly confident
4.20–5.00	completely confident

Table 3. Summary of Descriptive Statistics Results for "How Would You Rate Your Confidence in Doing the Following Tasks Associated With Technology Usage?"

Sub-factors	Item	*N*	Range	Minimum	Maximum	Mean	Std. Deviation
TPCK	1	42	4.00	1.00	5.00	3.38	.98
	2	42	4.00	1.00	5.00	3.33	.97
	3	42	4.00	1.00	5.00	3.38	1.01
TPK	4	42	4.00	1.00	5.00	3.21	.95
	5	42	4.00	1.00	5.00	3.19	.96
	6	42	4.00	1.00	5.00	3.50	1.08
	7	42	4.00	1.00	5.00	3.43	.99
	8	42	4.00	1.00	5.00	3.40	1.03
	9	42	4.00	1.00	5.00	3.50	1.08
	10	42	3.00	2.00	5.00	3.45	.86
	11	42	4.00	1.00	5.00	3.26	1.06
TCK	12	42	4.00	1.00	5.00	3.16	1.16
	13	42	4.00	1.00	5.00	2.90	1.37
	14	42	4.00	1.00	5.00	2.88	1.32
	15	42	4.00	1.00	5.00	3.19	1.41
	16	42	4.00	1.00	5.00	3.00	1.43
TK	17	42	4.00	1.00	5.00	3.90	1.28
	18	42	4.00	1.00	5.00	4.07	.99
	19	42	4.00	1.00	5.00	3.54	1.10
	20	42	4.00	1.00	5.00	3.54	1.21
	21	42	3.00	2.00	5.00	3.64	1.03
	22	42	4.00	1.00	5.00	3.00	1.03
	23	42	4.00	1.00	5.00	2.59	1.16
	24	42	4.00	1.00	5.00	2.73	.91

Table 3 shows the range, minimum and maximum values, and standard deviation for each item. When the sub-factors are examined, the data reveals that for the TPK sub-factor the participants feel either fairly confident (5 items) or somewhat confident (3 items). The same is also true for the TK sub-factor. The mean values of all other items are in the "somewhat confident" range. Also, when the average values of the sub-factor scores are calculated as seen in table 4, there seems to be almost no difference between the average values of TPCK, TPK, and TK. The average value of TCK item scores is lower than the other 3 sub-factors. However, average item score values of all sub-scales are in the somewhat confident range, despite the fact that some item means have higher values. The findings reinforce Mishra and Koehler's assertion about technology usage in instruction (2006) "… merely knowing how to use technology is not the same as knowing how to teach with it".

Table 4. Summary of Descriptive Statistics Results for "How Would You Rate Your Confidence in Doing the Following Tasks Associated With Technology Usage?"

				Scale		**Item**	
Sub-Factors	**Number of Items**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Mean**	**Std. Deviation**
TPCK	3	3.00	15.00	10.09	2.65	3.36	.88
TPK	8	12.00	38.00	26.95	6.00	3.37	.75
TCK	5	5.00	25.00	15.14	5.38	3.03	1.07
TK	8	18.00	37.00	27.04	5.07	3.38	.06

Gender difference in the perceived confidence levels
The second research question was about gender difference in the perceived confidence level related to the four TPCK constructs. The results of the t-test are shown in table 5.

Table 5. The Perceived Confidence Levels According to Gender

	Gender	***N***	**Mean**	**Std. Deviation**	***t***	***P***
TPCK	Female	23	9.91	2.93	.48	.63
	Male	19	10.31	2.33		
TPK	Female	23	26.34	6.95	.74	.46
	Male	19	27.68	4.69		
TCK	Female	23	14.39	6.23	1.03	.30
	Male	19	16.05	4.11		
TK	Female	23	26.69	5.64	.50	.62
	Male	19	27.47	4.38		

$p < 0.05$

These findings show that there is no statistically significant difference with respect to gender, since the p values are all greater than .05. This means that both female and male participants have had the same level of confidence in all sub-factors of TPCK.

Re-evaluating the TPCK framework
In order to find an answer to the third research question "What do in-service science teachers' ratings of their perceived confidence levels related to TPCK say about the framework itself?" correlations among TPCK sub-scale were calculated, and shown in table 6.

Table 6. Correlations Among Subscale Variables for the Question, "How Would You Rate Your Confidence in Doing the Following Tasks Associated With Technology Usage?"

		TPCK	**TPK**	**TCK**	**TK**
TPCK	Pearson Correlation	–			
	Sig. (2-tailed)				
	N				
TPK	Pearson Correlation	.836**	–		
	Sig. (2-tailed)	.000			
	N	42			
TCK	Pearson Correlation	.347*	.534**	–	
	Sig. (2-tailed)	.025	.000		
	N	42	42		
TK	Pearson Correlation	.394**	.520**	.294	–
	Sig. (2-tailed)	.010	.000	.059	
	N	42	42	42	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Each PCK domain is complicated, muddled, and messy so that "PCK is not an easy task and its construct has fuzzy boundaries, demanding unusual and ephemeral clarity" (Gess-Newsome, 1999, p.10). TPCK conceptual framework is also complicated as Koehler and Mishra (2008, p. 22) elaborated, "Instead of applying technological tools to every content area uniformly, teachers should come to understand that the various affordances and constraints of technology differ by curricular subject-matter content or pedagogical approach."

Table 6 indicates that there exists a high correlation between TPCK and TPK (.836). Also, there are moderate correlations between TPK and TCK (.534), and between TPK and TK (.520). In other combinations of the four constructs the correlations are low (< .400). In the light of these findings we once more face the question of whether or not TCK, TK, TPK and TPCK are distinct domains of the suggested framework. When our findings are compared to the previous studies we see that there is partial agreement, for example, with the findings of Archambault and Crippen's (2009) study. While there is agreement about the correlations between TPCK and TPK (high and high in both studies), and TK and TPK (moderate and moderate in both studies), there is disagreement about correlations between TCK and TPK (high and moderate), and TPCK and TCK (high and low). Also there is disagreement on the two remaining correlations: TPCK and TK (moderate and low), and TCK and TK (moderate and low – non-significant).

From the pre-service teachers' responses to the survey and the correlations among TPCK constructs an expanded model of TPCK can be suggested at Figure 1. In this framework, technological knowledge is defined as using computer in daily life as, searching, communicating, technological content knowledge is preparing representations with technology in order to explain a specific concept or principle, technological pedagogical knowledge is giving instructions by the using technology for motivating learners, and technological pedagogical content knowledge is making representations with technology in order to explain a specific concept or principle and also using it in an instruction for facilitating learning with special instructional methods.

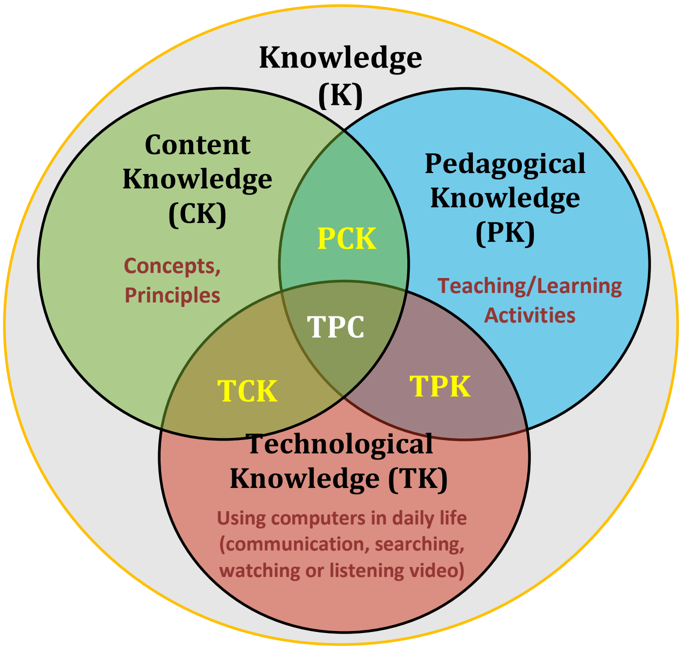

Figure 1. An expanded model of TPCK (adapted from Koehler and Mishra, 2006)

Views and prior experiences

The fourth research question was “What are the pre-service science teachers’ views about TRE and throughout their education how were their TRE experiences?” in order to find an answer to this question semi-structured interviews were conducted with 6 pre-service science teachers. Interviews were conducted with 3 male and 3 female pre-service science teachers. 3 questions were asked in order to understand how they create a TRE in science instruction. The questions of the interviews were “For what purposes does your teachers use computers in teaching science?”, What is the barriers to the TRE in teaching science?”, “How will you use computers when you are teaching science?”. Pre-service science teachers asserted that their teachers generally use computers for power point presentations and they rarely show videos or films during their science instruction. 6 of 5 pre-service science teachers indicated that they have never come up with any science animations, simulations but they knew animations from cartoons. From the interviews, most common barriers to TRE are; no access to internet at schools, difficult to find and do technology rich materials such as animations, simulations, video for every science subject, having classroom management problems. Pre-service science teachers tend to group the whole class and show the animations, simulations, video by the projector because their teachers have created TRE like this. They asserted that they sometimes stop the video or animation and ask questions to the class about the subject. But they think they need to learn how and when to use animations, simulations and videos in their instruction. As one pre-service teacher examples a learning experience from TRE in his science instruction,

> *I remember one of my science lessons at primary school. Our teacher showed us a video about blood cells and everybody in the class were concentrated and were surprised because we were watching something at the lessons this was amazing. We were used to listen the lecture of the teacher and solve some problems at science lessons. I can even remember this lesson now after 8 years.*

As another pre-service teacher describes technology rich science class,

> *I will use projectile when I am using computer in my class. I can find videos or animations about the topic and show the video or animation to the class. But I will use the video at the beginning of the lesson in order to motivate the students because if I use it after my lecture the children will watch the video as a film. I think like this.....*

CONCLUSION

This study shows that pre-service science teachers don’t feel confidence enough to create a TRE in science teaching. Because they are not used to be taught in a technology rich class and the mean of technology rich is watching videos or simulations with whole class for them. They don't feel confidence to teach in a technology rich class but they feel confidence using technology for when creating a power point presentation it is easy for them but using the power point presentation for teaching science is quite different and difficult. They need to learn how to enrich their lessons with TRE in science teaching and engage technology rich environments to science curriculum. From their learning experiences, they think that most of their teachers used technology as a replacement not enrichment that they only watched the screen of the computer with projector whole class, after the lecture of their teacher about the subject.

Sadler, Whitney, Shor, and Deutsch (1999) provide suggestions about characteristics of the effective computer assisted environments "Computer simulations can supplement laboratory exercises if they are designed to focus attention on formal variables, parameters, and frames of reference. A simulation can bring the student closer to a process by eliminating irrelevancies, providing real-time plotting of data following the user's specification of variables, and permitting the student to interrupt the event being represented and to update decisions about the selection of parameters and the nature of the data being collected. The decisions needed to control a simulation require the student to make predictions and confront his or her own theories". Pre-service science teachers need to develop TPCK of the most effective ways to teach various science concepts, principles, and now how to create a technology rich environment. Using technology in science classes requires teacher competences in technology. Teachers need to have a coherent knowledge about pedagogy and technology.

A technology rich inquiry-based environment provides opportunities for still another form of teaching science. Barab, Hay, Squire, Barnett, Schmidt, Karrigan, Yamagata-Lynch and Johnson (2000) indicate the central features of technology rich inquiry-based, participatory leaning environments as;

a. central component of these environments is that they are technology-rich, integrating *technology* as a tool for facilitating inquiry and/or other forms of authentic practice.
b. These environments must provide an opportunity for students to inquire into the phenomena they are learning, and not simply receive information about the phenomena.
c. Rather than telling students about practices, technology rich environments are designed to support students in participating in domain related practices.
d. These environments are intentionally designed to support the process of learning.

Successfully integrating technology into science education heavily relies on the development of well-built, coherent professional development programs that are designed with a clear understanding of how teachers need to use technology in their class in the most effective way. Developing TPCK has to be a critical goal of teacher education, professional development. As Shulman (1987) argued, "The goal of teacher education is not to indoctrinate or train teachers to behave in prescribed ways, but to educate teachers to reason soundly about their teaching as well as to perform skilfully. Sound reasoning requires both a process of thinking about what they are doing and an adequate base of facts, principles and experiences from which to reason. Teachers must learn to use their knowledge base to provide the grounds for choices and action (p. 13)". Pre-service teachers need to have the competence of technological pedagogical content knowledge in their special discipline.

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Mehmet Fatih Taşar
Associate Professor
Department of Primary Education, Science Education Program
Gazi University
Gazi Egitim Fakultesi
K Blok 210, 06500, Teknikokullar, Ankara
TURKEY
Email: mftasar@gazi.edu.tr

AUTHORS INDEX