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THE EFFECT OF INSTRUCTIONAL MATERIAL DESIGN PROCESS TO MATHEMATICS TEACHER CANDIDATES' TPACK

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Abstract:
It is inevitable to receive technology support for teacher training activities in this new era in which technology is at large in our lives. Sufficiency in terms of TPACK (Technology, Pedagogy and Content Knowledge) is among the basic conditions for being qualified teachers. For this reason, activities for teacher candidates' TPACK development should be involved in teacher training activities. TPACK expresses a combined knowledge, so complex activities should be consulted to increase this accumulation of knowledge. In this direction, the process of designing instructional materials allows learning by design and can address all of this integrated knowledge. In this study, in math education department of a state university in Turkey, a research was conducted with 19 teacher candidates studying in the third grade. Teacher candidates have been assigned tasks for designing materials they can use in their lessons. Before starting the tasks, all the teacher candidates filled out the TPACK scale (Schmidt et al., 2009) and pre-test data were generated. Among the task steps that were carried out, the prospective teachers shared the developmental stages of the material with their friends and enriched the materials in the direction of their comments. To gain more time, presentations and interpretations are conducted through a closed Facebook group. At the end of material development process which was carried out by sticking to learning by design principles, the TPACK scale was re-applied to all the teachers and the post test data of the study was obtained. Statistical analysis using the Wilcoxon signed rank test showed that there was a significant difference between the two tests and that all the teacher candidates increased their total scores. As a result of the study, it was found that the process of material development carried out by learning by design framework leads to a positive change in TPACK of teacher candidates.

Keywords: TPACK, teacher training, learning by design

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1. Introduction

Qualified teachers should be able to select appropriate learning techniques and use them effectively to ensure that the course subjects are understood at the highest level by students. For this reason, their content knowledge and the teaching techniques they use are important assets (Shulman, 1986). Great teachers are able to take advantage of their knowledge and shape their actions to adapt to classroom variables. These variables may include the student's interests, classroom materials, curricula structure, or lack of parent support. Only well-trained teachers can respond to classroom demands by combining knowledge and effective teaching techniques in the face of difficult situations. The primary goal of teacher training is to prepare qualified teachers, that is to say, to guide the pre-service teachers' knowledge, skills and technical competence to reach the maximum level (Darling-Hammond, 2012). Teachers need to have all required content knowledge and pedagogical knowledge, and maintain them always. Nevertheless, expectations for teachers to integrate educational technologies into their instructions are increasing rapidly (Johnson, Adams Becker, Estrada & Freeman, 2014). The need to integrate educational technologies with other types of knowledge has revealed the importance of pre-service teachers' technology competencies (Sang, Valcke, Braak & Tondeur, 2010).

2. Literature Review

2.1 Technological Pedagogical Content Knowledge (TPACK)

The Technological, Pedagogical and Content Knowledge (TPACK) framework, developed by Mishra and Koehler (2006), is a leading theory for determining teachers' knowledge of how to integrate technology into instructions. This framework explains what teachers need to have in order for them to become effective technology integrators.

The TPACK model is based on the teacher information model developed by Shulman (1986). Shulman's model describes the knowledge of teachers who solve complex problem situations in classroom successfully. His studies identified three broad categories of information that effective teachers have. The first content knowledge (CK) is the knowledge teachers have about the subject they teach. The second pedagogical information (PK) refers to the techniques teachers use to instruct their students. A third important field of knowledge identified by Shulman, pedagogical content knowledge (PCK), refers to the most appropriate techniques for teaching specific concepts in a given subject area. According to Shulman, teachers' choice of effective pedagogical techniques for successful instruction demonstrates that they possess a high level of PCK.

After the introduction of Shulman's theory, a great number of studies have been carried out that refer to educational technologies in the classroom (Johnson et al., 2014). Mishra and Koehler (2006) conclude Shulman's model of teacher information by adding a third main class of teacher knowledge. This category is titled Technology Knowledge.

The resultant model, called TPACK, contains information on how teachers apply technology to their training. The TPACK framework is a generative framework with many future applications (Gür & Karamete, 2015).

According to the TPACK framework, it is necessary to provide technological knowledge, pedagogical knowledge and content knowledge for an effective educational integration of technology. However, it is also necessary to consider the common points of them (Mishra and Koehler 2006; Polly 2011). TPACK model and the overlap of the three components are shown in Figure 1. In order to conduct a successful teacher training, the TPACK framework suggests that teacher candidates should be exposed to rich educational experiences for the development of TPACK components (Mishra and Koehler 2006). In these experiences, teacher candidates should focus on the central section in particular and be aware of the common influences of technology and pedagogy when teaching a particular content. Without regard to the intersection of technology, pedagogy and content, learning experiences that focus on only one or two of these knowledge components are insufficient to support the technology integration knowledge and skills of prospective teachers (Polly and Orrill, 2016).

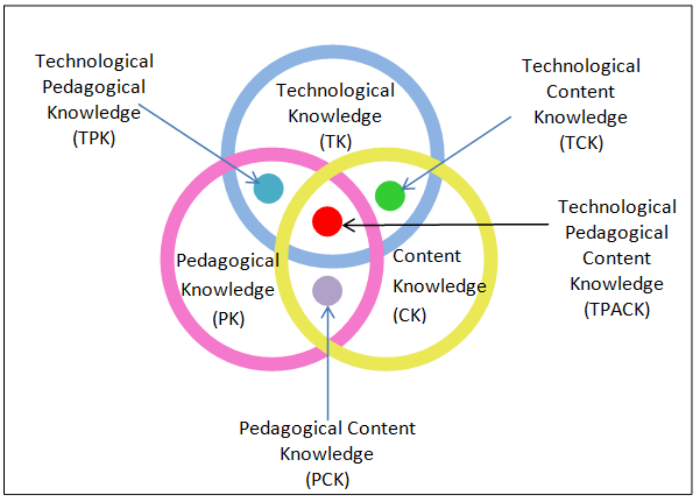

Figure 1: Scheme of TPACK (Mishra & Koehler, 2006)

2.2 Developing TPACK in Teacher Candidates

Most of the world-wide teacher training programs require teacher candidates to take a course in training technology or technology integration at the beginning of the teacher training program. Training technology courses offer opportunities for prospective teachers to learn and develop specific content for use in educational technology. Often these courses are combined with teacher training courses where teacher candidates can observe the integration of education and technology in real environments.

Researches on teacher education programs have indicated that there are many obstacles to preparing prospective teachers to integrate the technology effectively into the classrooms. There is a big difference between technology education in teacher training programs and technology integration in professional life (Sang et al. 2010). Furthermore, the discrepancies that teacher candidates face in teacher training programs result in the development of false beliefs about how technology can improve teaching and learning (Ottenbreit-Leftwich et al. 2010). These false beliefs are misleading during their professional lives both in themselves and their students. Although prospective teachers have sufficient knowledge of technology, integration is unsuccessful if they do not have the right pedagogical beliefs (Ertmer, 2005).

2.3 Learning by Design (LBD) as an approach for developing TPACK

The development of the basic structure of TPACK is possible with the production of original contents trough tangible activities. Learning about technology and pedagogy by actually using and designing educational technology to teach specific content is possible with working collaboratively in small groups to develop technology-rich solutions to authentic pedagogical problems (Koehler, Mishra, & Yahya, 2007). Design approaches ensure that important variables and relationships are discovered in the classrooms' naturalistic environment (Koh & Divaharan, 2013). Design activities offer great opportunities for participants to understand more broadly the relationship between content, pedagogy and technology (Koehler & Mishra, 2005a, 2005b; Kolodner, Gray & Fasse, 2002). They are successful to clarify misconceptions, touching the knowledge base through concrete and meaningful learning.

With the LBD being integrated into TPACK and being used in higher education, various researches showed its positive effects. Lu, L., Johnson, L., Tolley, L.M., Gilliard-Cook, T., and Lei, J., (2011). Jang & Chen, 2010; Alayyar, 2011. The main purpose was to improve the knowledge of technology integration and their results showed that design activities have a significant impact on TPACK development.

The aim of this study is to examine the effects of computer aided instructional material design process on Technological, Pedagogical and Content Knowledge (TPACK) of mathematics education teacher candidates. In this direction, answers to the following questions will be sought:

- Is there any significant difference between TPACK levels at the beginning and end of the material development process of the teacher candidates?
- Are there any significant differences in the sub-dimensions of TPACK levels?

3. Methods

In a framework of semi-experimental design, the main goal is to observe whether there is a difference between the data obtained by applying the same scale before and after the application on the same sample without the control group.

The sample of the research is composed of 19 teacher candidates who were studying in the 3rd grade in the Department of Mathematics Education of a state university in Turkey at the fall semester of 2016-2017. Four of the teacher candidates are male and fifteen of them are female.

3.1 Instruments

The "Technological Pedagogical Content Knowledge" scale developed by Schmidt et al. (2009) at the beginning and end of the semester was used as pretest - posttest to determine the TPACK levels of teacher candidates. The Turkish version of the scale and its adaptation for mathematics were carried out by Övez and Akyüz (2013). The scale's Cronbach Alpha reliability coefficient is 0.91.

3.2. Procedure

3.2.1 Organization and Application of Preliminary Tests

In the first week of the semester, the content of the course was explained briefly to the participants and information about the activities to be done during the semester is given. Technological pedagogical content knowledge scale (Schmidt, 2009; Övez and Akyüz, 2013) was distributed to the pre-service teachers in order to collect pre-test data.

3.2.2 Examining and Discussing Theoretical Subjects

In the second week of the lesson, the topics of instructional technologies, teaching materials and principles of preparing teaching materials were explained to the prospective teachers by the researcher in the class. Theoretical issues are addressed in the following order:

- Importance of Communication and Interaction for Learning;
- Teaching Technologies;
- Instructional Material Development Processes.

In the context of classroom discussion, prospective teachers have shared their own ideas about these topics and have already talked about their previous efforts to develop teaching materials. At the end of the course, Mathematics education materials on the education information networks were examined. Teacher candidates shared their ideas about these materials within the basic principles that teaching materials must possess. The main themes of the ideas shared were noted by the researcher.

During the third week in which the theoretical issues were examined; the importance of computer-based education, the types of computer-based education practices, and technological pedagogical content knowledge were taken into consider. For the next week, prospective teachers were asked to design their own design groups and design an instructional material.

3.2.3 Establishment of Design Groups and Determination of Subjects to Be Processed in Materials

Teacher candidates have formed two-person working groups with their chosen friends. As there were 19 active teacher candidates, 9 two-person groups were formed and one student preferred to work alone.

Teacher candidates were completely free to design the content of the material. Only, it was required to report the stages of preparing materials in the process. In order to ensure inter-group integrity and to write these reports in accordance with the steps of ADDIE, the general design model from instructional design models.

3.2.4 Making Design Plans and Sharing Ideas

At the end of the sixth week, all groups completed the analysis and design stages of material development processes and shared their design plans in the classroom. Teacher candidates made critics about; how they will be presented, the purpose of the material (teaching or practice), the tools to be used, and the basic structures of flow charts, the target audience, and the readiness requirements. As a result of the criticisms made, the basic elements that need to be taken care of during the development phase were highlighted and the design plans were rearranged.

3.2.5 Development of Materials, Analysis and Presentation of Final Designs

The second half of the semester continued with presentation, interpretation, determination of strengths and weaknesses of the developed materials, and re-design in line with them. In order to ensure that all participants are active in the process, the criticism and evaluation of the materials have continued beyond the course. To ensure this, the material presentations of candidate teachers were recorded as videos, and these videos were uploaded via Facebook, which is a social network. Teacher candidates have the opportunity to review and criticize each other's materials through this platform outside the classroom.

Teacher candidates used an online questionnaire that was activated by the researcher at certain times while evaluating the materials that other groups created. This questionnaire, which was prepared and shared through Google Forms, gave participants the opportunity to present more objective criticisms by keeping their identities confidential to the members of the group they were evaluating. The data from the questionnaire was added by the researcher as a comment to the relevant shares on Facebook, and the materials were refreshed during the redesign process.

3.2.6 Completion of Designs and Application of Post-Tests

At the end of the semester, all groups periodically demonstrated their final designs by strengthening the weaknesses of the materials in the direction of on-going evaluations. For the final state of designs, the questionnaire used in the development process was reapplied and the necessary data was obtained for the analysis of the development process.

Focus group discussions and individual interviews were conducted for the overall evaluation of the material development process, which has been continuing throughout the semester. The interviews were taken under the approval of the interviewed teacher candidates and converted to texts. Finally, post-test data were obtained by applying the TPACK scale applied at the beginning of the semester.

4. Findings

The Wilcoxon signed-rank test was employed to determine the changes in participants' TPACK after their learning by design based coursework. The descriptive data that identified the changes in participants TPACK among the total scores as recorded by the pre- and post-test TPACK surveys are displayed in Table 1.

Table 1: Descriptive Statistics of Pre- and Post-test of TPACK Scale

	pretest	posttest
N	19	19
Mean	92.4737	114.6842
Std. Deviation	6.30140	9.30981
Minimum	85	105
Maximum	95	129

The null-hypothesis for the Wilcoxon signed-rank test, employed to determine if there was a statistically significant difference between participants' pre- and post-test total score on the TPACK, was that there was no difference between the mean scores for the Pre-TPACK and Post-TPACK samples. The Wilcoxon signed-rank test indicated a significant value of 0.000. This value is below the p = 0.05 threshold, indicating a rejection of the null hypothesis. Therefore, Post-test samples were significantly higher than the mean score of the Pre-test samples. These results are illustrated in Table 2.

Table 2: Test Statistics of Comparison of Pre-test and Post-test

	posttest - pretest
Z	-3.825[b]
Asymp. Sig. (2-tailed)	.000

When the scores of all sub categories of the scale and their averages are examined, it is seen that the scores obtained from the final test are higher than the scores obtained from the preliminary test. In order to be able to defend such an ambitious result using a nonparametric test by working on such a small sample, these results must be supported absolutely by qualitative data.

When the scores obtained are examined separately for the subscales of the TPACK scale, it is seen that the post test scores for all dimensions are higher than the pre test scores.

Table 3: Subscale Scores of TPACK

	Z	ASymp. Sig. (2-tailed)
TK – Technology Knowledge	-3.834[b]	.000
CK – Content Knowledge	-3.362[b]	.000
PCK – Pedagogical Content Knowledge	-3.727[b]	.000
TPACK – Technological Pedagogical and Content Knowledge	-3.829[b]	.000

In this respect, it can be clearly seen that the learning by design activities carried out contributed positively to the TPACK development of teacher candidates.

When item by item differences are examined, it is seen that there is only one scale item which shows positive change in common in all teacher candidates participating in sampling:

> *"I can adapt the use of the technologies that I am learning about to different teaching activities"* (Schmidt et al. 2009).

The positive changes in the responses given by all prospective teachers to this item are important signs for TPACK development. Because this scale item refers to the integration of existing knowledge and methods in order to transfer the technology knowledge to be used in different content, activities or disciplines.

The greatest negative change in total is concentrated in 2 items. It is seen that 3 teacher candidates gave lower scores than pre-tests in both items.

1. *"I can adapt my teaching based upon what students currently understand or do not understand."*
2. *"I can learn technology easily"* (Schmidt et. al., 2009).

Observation of the negative changes in the first item is expected, as teacher candidates have no teaching experience and have never done any instructional design before. To keep the teaching dynamic according to the level of comprehension of the students requires mastery of pedagogy and content knowledge at a high level. Therefore, these negative changes can be interpreted as the fact that the teacher candidates are in the process of their own accumulation. It is thought that the negative changes of the second item are also caused by the compulsive activities in the design works. Throughout their design work, tasks have been assigned to prospective teachers to select, learn and pass on the technologies they will use. It is thought that having 1-2 weeks of time to learn the technological applications they have never encountered caused these negative changes to occur.

5. Results and Discussion

As a result of the study, it can be said that the material development processes carried out with learning by design principles can be used as an effective tool to develop TPACK of teacher candidates. Many previous studies have already supported this end result (Lu et al 2011, Jang & Chen 2010, Alayyar, 2011). Furthermore, all the findings obtained have undergone a positive change is an indication of how powerful the used method is in developing TPACK.

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