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INTEGRATING TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPCK) FRAMEWORK INTO TEACHER EDUCATION[1]

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With the advancements in digital technologies in the twenty-first century, there is a growing need in preparing future citizens for working and continually learning with technology. Therefore, preparation of teachers to teach in ways that help them to guide their students in learning with appropriate technologies should need to be carefully reconsidered (Niess, 2008). In the recent literature, Technological Pedagogical Content Knowledge (TPCK) is described as the knowledge and skills that teachers need in order to meaningfully integrate technology into instruction (Mishra & Koehler, 2006). This paper aims to show how TPCK framework can be used to design and deliver mathematics teaching courses in pre-service mathematics teacher education. Considering the work of Grossman (1990), five components of TPCK were specified and used in the course design which is proposed as a model for other subject areas. This paper presents in detail how TPCK framework with its five components was used to prepare the content of the course and chose the method of delivery.

Keywords: Technological Pedagogical Content Knowledge, Mathematics Teacher Education, Pre-service Mathematics Teachers

Introduction

With the advancements in digital technologies in the twenty-first century, there is a growing need in preparing future citizens for working and continually learning with technology. Research studies suggest that technology should be an important element of instruction as it has become an important part of our everyday life (Hazzan, 2003). Various curriculum statements emphasize that technology should be an integral part of learning and teaching (NCTM, 2000; ISTE, 2000).

In the past three decades, technology has been used in the teaching of mathematics with the availability of tools such as educational software, graphical calculators and interactive whiteboards. Research studies indicate that using technology during instruction promotes conceptual understanding in mathematics (Harvey, Waits & Demana 1995; Heid, 1995; Farrell, 1996; Noss & Hoyles, 1996; Habre & Abboud 2006).

On the other hand, the existence of technological hardware and software in schools is certainly not the unique factor that affects successful technology integration. More importantly,

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teachers should be prepared to use technology in their classrooms in effective ways. Teacher education programs which aim to develop this knowledge adopted two different approaches. First, there are programs with a single course which aims to teach pre-service teachers how to use the technology. Second, there are teacher education programs which aim to teach pre-service teachers how to teach with the technology. The latter kind of programs includes courses which focus on content-specific applications and school practicum to integrate technology into instruction (Duhaney, 2001; Wetzel & Zambo, 1996; Young *et al*. 2000). There is growing literature which identifies how this more integrated approach helps pre-service teachers develop the knowledge and skills in successfully integrating technology into their teaching (De Jong et al., 2005, Kaya, 2009).

Considering this gap in the literature, this paper introduces a pre-service mathematics teacher education program which aims to develop the knowledge of technology integration into instruction. The program development is part of a research project which also examines the development of pre-service mathematics teachers. The aim of this paper is restricted to the description of the course design.

Theoretical Underpinning of the Course Design

Recently, the knowledge required for successful technology integration is defined as technological pedagogical content knowledge (Pierson, 1999; Niess, 2005). Technological pedagogical content knowledge (TPCK) framework is built on Shulman's (1986, 1987) description of pedagogical content knowledge which is defined as the intersection of two knowledge domains, namely content knowledge and pedagogical knowledge. Adding the technology component to the framework, Pierson (1999) and Niess (2005) describe TPCK as a combination of three types of knowledge: (a) content knowledge, (b) pedagogical knowledge, (c) technological knowledge. Pierson (1999) illustrates TPCK as the intersection of three sets each of which represents different domains of knowledge (See Figure 1).

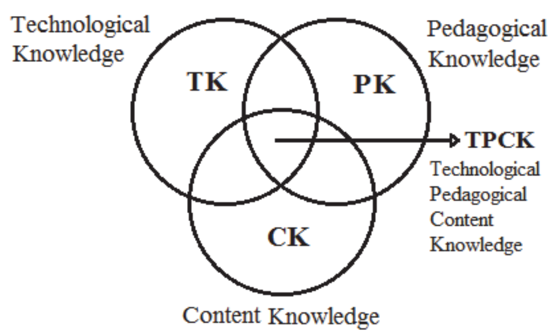

Figure 1. Technological Pedagogical Content Knowledge.

Special attention should be paid to the way TPCK is illustrated pictorially. As Gess-Newsome (1999) emphasizes PCK is a conceptual tool which helps us to understand the influence of teachers' knowledge on instruction by reducing the conceptual and contextual complexity of teaching. The intersection of sets is used to reduce this complexity. Therefore, the model should be considered with its limitations. First of all, the idea of intersection is problematic since one can intersect only the same kinds of things. Second, sets could have fuzzy boundaries (Gess-Newsome, 1999; Magnusson, Krajcik & Borko, 1999). Therefore, Gess-

Newsome (1999) distinguishes between integrative and transformative model of PCK which can be also applied to TPCK. She explains it with an analogy from chemistry where integrative model corresponds to mixture of elements and transformative model corresponds to a compound. In integrative model, elements of knowledge from subject matter, pedagogical and technological domains are developed separately and melded in classroom practice. In transformative model, initial knowledge domains are combined into new forms of knowledge which are more powerful than its constituent parts. For example, technological pedagogical knowledge is different from and more powerful than pedagogical and technological knowledge. In that sense, Mishra & Koehler (2006) describe intersections of different knowledge domains (See Figure 2). Pedagogical content knowledge (PCK) is concerned with the structure, organization, management, and teaching strategies for how particular subject matter is taught. Technological content knowledge (TCK) is related to the way a particular subject matter is represented in technology-rich environments. Teaching with technology requires knowing not only the subject but also the way subject matter can be changed with the application of technology and this knowledge is called TCK. Technological pedagogical knowledge (TPK) is concerned with how teaching and learning change as a result of integrating technology into instruction and how a teacher should be able to choose a particular tool for a particular task considering its affordances and limitations. Technological pedagogical content knowledge (TPCK) "is an emergent form of knowledge that goes beyond all three components" (p. 1028). According to transformative model TPCK is different from "knowledge of a disciplinary or technology expert and also from the general pedagogical knowledge shared by teachers across disciplines" (p. 1029).

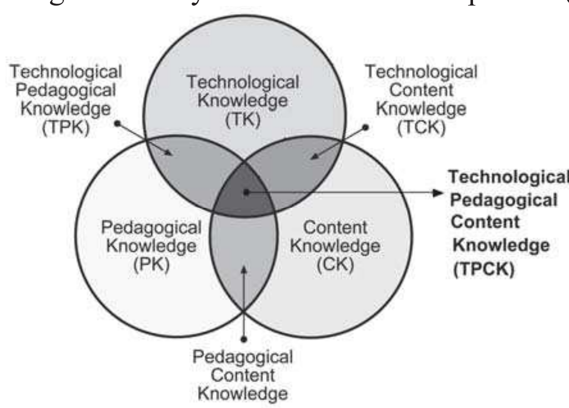

Figure 2. Intersection of knowledge domains of TPCK (Reproduced by permission of the publisher, © 2012 by tpack.org)

Niess (2005) examines the components of TPCK in more detail and adopted Grossman's (1989, 1990) four components of PCK to define the components of TPCK: (1) an overarching conception of what it means to teach a particular subject integrating technology in the learning, (2) knowledge of instructional strategies and representation for teaching particular topics with technology, (3) knowledge of students' understanding, thinking, and learning with technology in a particular subject, (4) knowledge of curriculum and curriculum materials that integrate technology with learning in the subject area. Although Pierson (1999) and Niess (2005) have provided a framework for TPCK, their studies fell short in providing sufficient details regarding the developmental process of TPCK for pre-service teachers. Furthermore, the content dimension of TPCK framework has been neglected in the literature.

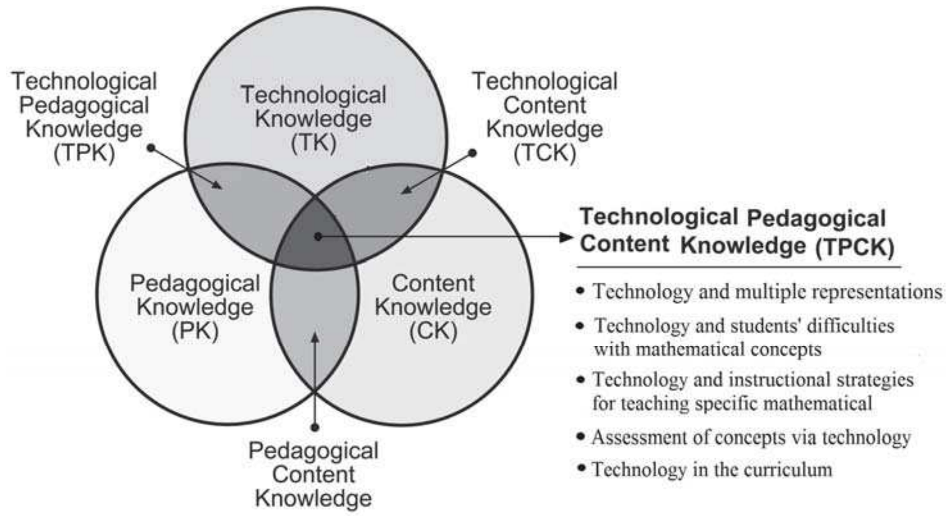

Figure 3. Components of Technological Pedagogical Content Knowledge used in the study (Reproduced by permission of the publisher, © 2012 by tpack.org)

In this study, TPCK framework is used for course design by bringing the content dimension into play. The components of TPCK are determined as follows: (a) Technology and multiple representations, (b) technology and students' difficulties with and misconceptions of specific concepts, (c) technology and instructional strategies and methods for teaching a specific concept, (d) assessment of concepts via technology, (e) technology in the curriculum (See Figure 3).

The course design using TPCK framework

In this section, a detailed description of how TPCK framework and its components are used to design the course will be given. The course design includes four basic phases: (a) Specifying the objectives of the course, (b) Preparing the content of the course, (c) Specifying learning and teaching situations, (d) Assessment of the objectives. Each of these phases will be explained in the following subsections.

Objectives of the course: As the first phase of the course design, objectives of the course were specified for each knowledge domains (e.g. PCK, TK, TCK, TPCK) and their corresponding components. Examples of objectives are presented in the table below:

- Pre-service teachers will be able to use multiple representations and links between them in the teaching of mathematics (PCK).
- Pre-service teachers will be able to use multiple representations and links between them in the teaching of mathematics using technological tools (TPCK).
- Pre-service teachers will be able to use affordances and limitations of the specific technological tools in the teaching of specific mathematical software (TCK).

Content of the course: Content of the course was prepared based on the objectives specified and the related mathematics education literature. Components of TPCK were exemplified by using specific mathematical concepts (namely function and derivative). In other words, the course initially aimed to develop TPCK of function and TPCK of derivative. This was targeted to be achieved in a term during two courses: Mathematics Teaching Method Course and Instructional Technologies and Material Development Course. This content-specific approach was followed by other mathematical concepts such as limit, continuity, radian, integral and probability. TPCK development was aimed for these concepts for the next term. Choice of software was based on mathematics education literature and technology component of the course aimed to develop technical knowledge and skills for using these tools.

For each component of TPCK, related mathematics education literature was reviewed in the contexts of function and derivative. For example, relating to "technology and multiple representation" component, mathematics education literature was reviewed and examples of multiple representations of functions and derivative in technology-rich environments were selected. Discussion points were specified on how to make links between various representations with the help of technology. For the second component - technology and students' difficulties with and misconceptions of specific concepts - students' difficulties with functions and derivative were specified considering the related mathematics education literature. Discussion points on how to overcome these difficulties using technology were used. In relation to the third component - technology and instructional strategies and methods for teaching a specific concept - examples of lesson plans on how to introduce function and derivative concepts using technology-enhanced teaching methods were given. For the fourth component - assessment of concepts via technology - examples of how to assess learning functions and derivative in technology-rich environments were given. Finally, for the fifth component - technology in the curriculum - discussion points on how to evaluate the curriculum materials concerning functions and derivative concepts were specified.

Learning and teaching situations: The content, as described above, was aimed to be delivered in a student-centered learning environment. Modules called workshops are planned where pre-service teachers were actively involved and performed hands-on activities. Four main workshops during which PCK and TPCK were exemplified using function and derivative concepts were conducted:

- PCK workshop: Five components were discussed in non-technology contexts e.g. multiple representations of functions and derivative and links between them without using technology.
- TK workshop: Technical knowledge and skills of using various software such as Geogebra, Cabri Geometry, Graphic Calculus, Derive, Excel and Logo.
- TCK workshop: How to represent function and derivative concepts in technology-rich environments. In other words, technological content of software for function and derivative.
- TPCK workshop: Five components were discussed in technology contexts e.g. multiple representations of functions and derivative and links between them using technology and pedagogical implications of this e.g. affordances and limitations of using technology for the learning and teaching of function and derivative concepts.

TK, TCK and TPCK workshops were conducted in a computer lab in an interactive way. Pre-service mathematics teachers prepared lesson plans which introduce function and derivative concepts before and after the workshops. Ten out of forty pre-service teachers did micro-teaching lessons where they taught their peers. They were encouraged to reflect on these lesson plans and micro-teaching lessons especially after they were involved in the workshops.

The first set of workshops, as described above, lasted for a term. In the next term, pre-service mathematics teachers planned and conducted their own workshops focusing on different mathematical concepts such as limit, continuity, radian, integral and probability. As similar to the previous workshops, pre-service teachers' own workshops embraced a student-centered learning environment. Finally, pre-service teachers had chances to integrate technology into their teaching in partnership schools where they collaborated with school teachers.

Assessment of the program (Data collection tools): Effectiveness of the program is assessed using various data collection tools such as lesson plans, observation forms, semi-structured interviews, evaluation form for the course and self-assessment forms. Observation form includes items which focus on each component of TPCK and was used to observe the micro-teaching lessons. It was used not only as a data collection tool by the researcher but also as a learning tool for pre-service teachers. Semi-structured interviews include questions to explore each component of TPCK. First, pre-service teachers were interviewed on their lesson preparations. Second, pre-service teachers reflected on their lessons in terms of each component e.g. how they used technology to make links between multiple representations. Evaluation forms include items which aim to explore participants' views on the content and method of the course. Self-assessment forms include objectives of the course as described above and participants chose to what extent they attained each objective.

Discussion and Conclusion

This paper described how TPCK framework can be used to design and deliver mathematics teaching courses in pre-service mathematics teacher education. In this section, main characteristics of the program will be discussed.

As mentioned above, the related literature fell short in providing sufficient details regarding the developmental process of TPCK for pre-service teachers and especially content dimension of TPCK framework has been neglected in the literature. As described in this study, TPCK framework is used for course design by bringing the content dimension into play. TPCK framework was exemplified by two mathematical concepts: function and derivative. On the one hand, this approach aims to develop TPCK of specific mathematical concepts. On the other hand, components of TPCK for any content were aimed to be developed. To do that, pre-service teachers were asked to work on the components of TPCK for other mathematical concepts by conducting their own workshops.

One of the important characteristic of the program is the method embraced to deliver the content of the course. Participants were involved in hand-on activities and actively participated in the workshops. Examples used to explore each component of TPCK were discussed with peers in the classroom. Furthermore, pre-service teachers applied TPCK framework to various mathematical concepts by conducting their own workshops.

Another characteristic of the program is concerned with the technological tools that were used in the workshops. A large repertoire of software was used during the program. Furthermore, as pre-service teachers planned and conducted their own workhsops they introduced other software.

The aim of this study is restricted to the description of how TPCK framework could be integrated into a teacher education program. Pre-service mathematics teachers' development of TPCK is beyond the scope of this paper. Therefore, findings concerning this development are not presented here. Various papers discuss aspects of participants' TPCK development. Ozmantar *et al*. (2010) presents a case study which demonstrates how one of the participants involved in the program successfully integrate technology to use multiple representations of derivative concept and make links between them. Bingölbali *et al*. (2011) focus on one particular component of PCK and investigate forty participants' views of the sources of students' difficulties in mathematics. Akkoç (2011) explored two of the participants' development of TPCK with regard to a particular component: technology and students' difficulties with and misconceptions of specific concepts. She investigated two participants' developments in the context of radian concept using a case study methodology. Akkoç (2012), on the other hand, focuses on forty participants' development of TPCK in terms of assessment component. Ongoing research findings could be obtained from the web site http://mimoza.marmara.edu.tr/~hakkoc/TPCK.htm

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