EXPLORING THE TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE[1]

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Abstract

This paper focuses on the question: what teachers and/or pre-service teachers need to know in order to appropriately integrate technology into their teaching. In the literature, a theoretical framework called "Technological Pedagogical Content Knowledge (TPCK)" is proposed to investigate this question. This paper aims to contribute to the discussion group by exploring technological pedagogical content knowledge on the basis of data obtained from micro-teaching activities in a mathematics teacher education program in Turkey.

INTRODUCTION

In Turkey, recent reforms have adopted a constructivist approach to teaching and learning of mathematics. In terms of technology, the recent curriculum vision emphasises that the technology is not an option but should be an integral part of mathematics instruction. To this end, schools nationwide have been equipped with computers supplied by the Ministry of Education. However, data from the research conducted by the Ministry of Education have shown that most of the computers provided to the schools have not been used by the teachers at all (Aktürk, 2007). This indicates the importance of training teachers in using technology, but not just for the technical knowledge of using it but also for the knowledge and ability to use the technology as an effective and purposeful tool. In the literature, this knowledge is defined as Technological Pedagogical Content Knowledge (Pierson, 1999; Niess, 2005).

TPCK FRAMEWORK IN TEACHER EDUCATION LITERATURE

TPCK framework was originally derived from the idea of "Pedagogical Content Knowledge (PCK)" which was proposed by Shulman (1986, 1987). Shulman (1987) emphasised the importance of "subject matter for teaching" and proposed pedagogical content knowledge (PCK) as an important domain of teachers' knowledge. PCK can be represented as an amalgam of content knowledge and pedagogical knowledge. Shulman (1987) proposed that "pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue" (p. 8). The availability and common usage of technology in education has led Pierson (1999) and Niess (2005) to add technology component to the PCK framework and that has resulted in the development of the notion of "Technological Pedagogical Content Knowledge (TPCK)". They described TPCK as a combination of three types of knowledge: (a) content knowledge, (b) pedagogical knowledge, that is, the structure, organization, management, and teaching strategies for how particular

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subject matter is taught, (c) technological knowledge including the basic operational skills of technologies and how technologies can be used in the classroom.

Mishra & Koehler (2006) illustrate TPCK as an intersection of these three knowledge categories (See Figure1). As can be seen in Figure 1, intersection of pairs of different categories of knowledge are defined as TCK (e.g. understanding the kinds of representations that software offers for a concept) and TPK (knowing how teaching might change as a result of using a variety of technologies available). In this paper, TPCK with special attention to the content dimension will be the focus of our discussion.

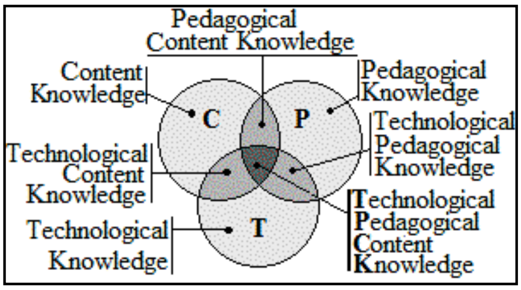

Figure 1. Representation of TPCK

QUESTIONS FOR DISCUSSION

During the discussion sessions at ICME, we will attend to the following questions with regard to TPCK framework:

1. How can CK, PK, PCK, TCK, TPK and TPCK in Figure 1 be conceptualised with regard to teaching mathematics?
2. What are the relationships between and interactions among CK, PK, PCK, TCK, TPK and TPCK in Figure 1?
3. How can teacher educators analyse and monitor pre-service teachers' teaching practices of integrating technology in terms of TPCK framework?
4. How can pre-service teachers' difficulties in integrating technology into their teaching under the TPCK framework be investigated?
5. How can teacher education programs help pre-service mathematics teachers for a better integration of technology into teaching using the TPCK framework?

ANALYSIS OF TPCK

In the following two sections we will attend to these questions and discuss TPCK in two different contexts. In the first section, we provide an example of "polygons" to merely exemplify the components of the TPCK framework in relation to the integration of technology into instruction. In the second section, we present data from a case study in which a pre-service teacher teaches "derivative at a point" using technology.

An example of TPCK analysis at elementary level

Suppose a teacher teaches the relationships between angles and sides of regular convex polygons using technology. We will analyse what CK, PK, PCK, TCK, TPK and TPCK means in this context. Content knowledge (CK) is the knowledge of content to be taught e.g. "what are the relationships between the angles and sides of regular polygons?". Mathematical content is presented as below:

Table 1 – *Properties of regular polygons*

a. An internal angle of a regular polygon is equal to [(n - 2).180°]/n
b. An external angle of a regular polygon is equal to 360°/n

Pedagogical Knowledge (PK) is the general pedagogical knowledge that could come into play during teaching such as knowledge of educational aims, learners and learning, instructional principles, classroom management (Grossman, 1990).

Pedagogical Content Knowledge (PCK) is the amalgam of content knowledge and pedagogical knowledge (Shulman, 1987). Following questions are the concerns of PCK: How can a teacher make angle-side relationships of regular polygons comprehensible for students? Does the teacher only state these properties or help his/her students to discover the properties for themselves by exploring the relationships starting with specific cases and making generalisations? What are the appropriate instructional strategies for teaching it? These are critical questions that inform the teaching process.

Technological Knowledge (TK) involves the skills required to operate particular technologies. A teacher should know how to draw regular polygons using various software available. Below we illustrate an example using two software: Cabri Geometry and LOGO (see Figure 2 and 3).

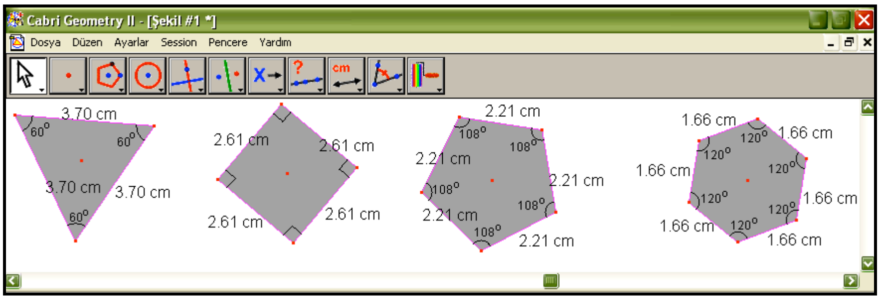

Figure 2. Representation of regular polygons using Cabri

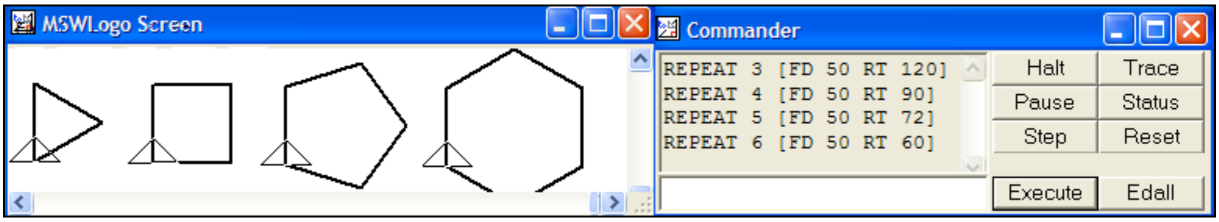

Figure 3. Representations of polygons using LOGO

Each software has its own technical procedures. For instance, in Cabri Geometry, polygons can be drawn automatically by specifying the number of sides and the length of each side. On the other hand, in LOGO, one should determine how much to turn, that is the value of turning angle (exterior angle) as well as the length of each side. For a successful integration of technology, developing these technical skills is important, which, however, is not sufficient in itself. Knowing how to use technology is one thing but knowing how to teach with it is another. Teachers should combine this technical knowledge with their TPK and PCK.

TPK (Technological Pedagogical Knowledge) is concerned with knowing how teaching might change as a result of using a variety of technologies available. In the case of our example, this includes an understanding that a range of tools exist for teaching regular polygons, strategies for using the tool's affordances, and knowledge of pedagogical strategies and the ability to apply those strategies for the use of technologies (Mishra & Koehler, 2006). As mentioned above, each software has its own technical procedures to follow. In fact, these differences have pedagogical implications as well. For instance, Seymour Papert (1980), the designer of LOGO, claims that, instead of having computers programming students, students should learn how to program and control the computer using programming languages. Awareness of these pedagogical underpinnings of various softwares and the changing role of a teacher in the classroom is the concern of TPK.

TPCK (Technological Pedagogical Content Knowledge) is the amalgam of TPK, PCK and TCK. For instance, in the case of our example, following questions are the concerns of TPCK: How the use of LOGO and/or Cabri Geometry provides opportunities for students to discover the relationships between angles and sides of regular polygons? (e.g. In LOGO, since the user should decide the turning angle him/herself, it provides opportunities for students to explore that the number of turns times the turning angle gives the value for a complete turn which is 360°. Therefore, it has a potential to help students to discover that an external angle is 360/n°). What kinds of pedagogical principles are important to make use of these opportunities? How can we address students' difficulties with learning angle-side relationships by making use of the technological content offered by various softwares?

An example of TPCK analysis at high school level

In this section, we illustrate the analysis of TPCK in the context of teaching derivative using the data from a case study. We aim to bring the content dimension into play in our analysis of TPCK. In the following sections, we present data from one pre-service teacher's (called Sena) microteaching videos, lesson plans and interviews which will be examined with particular attention to the three components of the TPCK framework, namely PCK, TCK, TPK (see Figure 1). In terms of PCK, we will focus on only one of its components: knowledge of strategies and representations for teaching (Shulman, 1987; Grossman, 1990).

When investigating the delivery of derivative at a point with the use of technology from the lenses of TPCK, we will focus on the content dimension considering the three aspects of derivative which have also been investigated in the literature as the areas of student difficulties: derivative-rate of change relationship (Orton, 1983), derivative-slope relationship (Amit & Vinner, 1990) and derivative-limit relationship (Orton, 1983).

Methodology

The study that gave rise to this study set out to explore the development of pre-service secondary mathematics teachers' TPCK during a mathematics teacher education program in a large Turkish university in İstanbul. Participants are required to take general and content specific pedagogical courses at the university and do teaching practices in schools. We collected the data during the period of pre-service teachers' micro-teaching activities in which the participants used Graphic Calculus software as a tool for teaching. They prepared lesson plans and teaching notes and taught various subjects such as function, limit, derivative and integral as their peers followed their teaching, taking a role of a student. They were interviewed after micro-teaching to reflect on their planning and teaching. The TPCK framework was used to analyse the data obtained from micro-teaching videos, lesson plans and interviews.

Results

This section presents the analysis of Sena's CK, TPK, TCK, PCK and TPCK respectively. *Content knowledge (CK) of derivative at a point:* After her micro-teaching Sena took a derivative test and her written responses to test questions were analysed. Questions aimed to assess her understanding of derivative in three aspects of derivative as described above. She successfully responded to the rate of change items and intuitively explained the limiting process. However, she could not explain the graphical meaning of derivative.

Technological Pedagogical Knowledge (TPK): In the micro-teaching, Sena made use of technology only for teacher-demonstration without having students try and discover the ideas for themselves using their own computers which were avaliable to them. During the interviews, she stated that she intentionally preferred this approach believing that technology should not weaken her authority as a teacher. This reveals, we think, her dificulties with coping with the changing roles of a teacher with the existence of a new media in the classroom. The role of the teacher in the classroom is crucial in terms of TPK and affects delivery of the content.

Technological Content Knowledge (TCK) of derivative at a point: The software (a Turkish version of Graphic Calculus) Sena used provides graphical and numerical representations of derivative at a point which are dynamically linked as can be seen in Figure 4. TCK is concerned with an understanding of this technological content. During the interview, Sena was asked to use the software and successfully performed the activities of the software. However, the question is whether she could use this technical knowledge to relate three aspects of derivative at a point using the software.

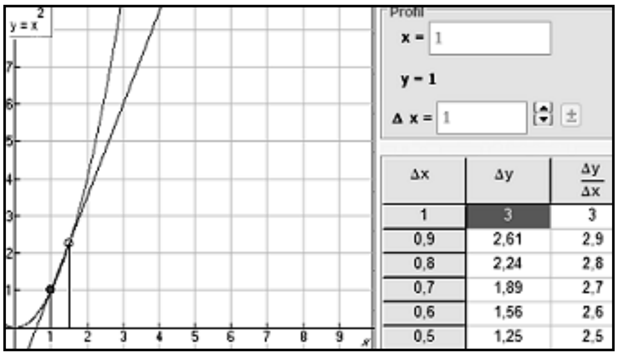

Figure 4. Technology content for derivative

Pedagogical Content Knowledge (PCK) of derivative at a point: During microteaching, Sena privileged the notion of rate of change. She focused on values of rate of change around $x = 2$ using the software (see Figure 5). However, she did not explain the idea of 'instantaneous rate of change'. She also did not give an account of the graphical meaning of rate of change by using the graphical representation of tangents approaching to the slope which dynamically progresses simultaneously with the table of values (see Figure 4).

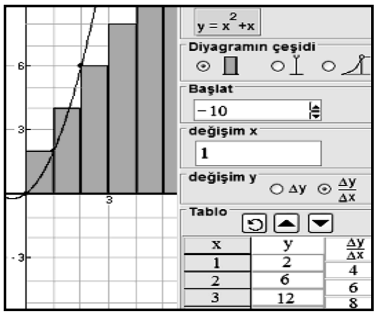

Figure 5. Rate of change activity

Technological Pedagogical Content Knowledge (TPCK) of derivative at a point: The analysis of Sena's CK, PCK, TCK and TPK enabled us to gain insights into her TPCK. Although Sena could perform the technical procedures of the software, she could not relate three aspects of derivative at a point in a coherent way during her teaching. She did not explain the graphical interpretation of derivative. However, the activity of the software has a potential for addressing the relationship between graphical meaning and the notion of rate of change. It provides graphical representation of secants approaching to the tangent which dynamically progresses simultaneously with the table of values of rate of change (see Figure 2). Sena could not use this potential of the software. This indicates why TPCK of derivative is not just a mere understanding of TCK of derivative. One should interpret the pedagogical idea behind the technological content and also combine his/her TCK with PCK and TPK. As described above, lack of TPK also affected Sena's TPCK. She was reluctant to change her role as a teacher and this, we feel, hindered a successful technology integration as she prefered her students not to use their computers since it might weaken her authority and control as a teacher.

DISCUSSION

The analysis of data under TPCK framework provides possible answers to the questions for discussion as posed above. Analysing TPCK with its components was useful to diagnose pre-service teachers' difficulties with integration of technology into instruction and areas which need development for a successful integration. Both the data from Sena's teaching and the example regarding polygons illustrate how these components have the potential to enrich and hinder one another. The notion of TPCK, therefore, we think, provides a useful framework to analyse and monitor not only pre-service teachers' teaching practices of integrating technology but also in-service teachers' integration of technology in their teaching. The TPCK framework can effectively be used to determine the content of courses such as 'Instructional Technologies for Mathematics Teaching' for pre-service teachers and of workshops for in-service teacher training programs in attempts to achieve a successful integration of technology into instruction.

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