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Teaching Mathematics Using Technological Pedagogical Content Knowledge (TPACK)

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Abstract

Mathematics subject plays very important role to developing critical thinking, problem solving skill and reasoning. It contains abstract content which need to elaboration with various techniques or strategies. So mathematics teachers plays vital role to inculcating the concepts to the students. They use various instructional strategies, and pedagogical approaches to solve the problem. In the present scenario, there are so many emerging techniques has been developed which can help mathematics teachers to transfer the concept to the students. TPACK is the most favourable pedagogical approach which supports teacher to their teaching effective and enjoyable. TPACK stands for Technological Pedagogical Content Knowledge which has been derived from Schulman's Pedagogical Content Knowledge (PCK) which refers to technological perspectives of pedagogical content knowledge. TPACK consist of seven different types of knowledge-Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK) and Technological Pedagogical Content Knowledge (TPACK) in which first three is the basic and other four are comes from intersection of TK, PK, and CK. In Short we can say that it the intersection of technology, pedagogy and content knowledge. TPACK basically emphasize on teaching with integrated technological pedagogy. It's major goal to develop the educational practices with the successful integration of technology. The main aim of this paper is to know the concept of Technological Pedagogical Content Knowledge (TPACK) and to find out how it is important to mathematics teachers to inculcating the concept in classroom.

Keywords: Mathematics, Technology, TPACK , Teaching

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Introduction

Teachers play key role to fulfil the educational need to the society, giving quality education, and achieving learning goal to the students. They have more impact on learning than any other factors controlled by school system, including class size, school size and the quality of school programs or even which school a student is attending. On the other hand mathematics teaching becoming very complex in technological era where knowledge is spreading to all over the globe within a second and this rapid developments in science and technology demand for better educated students, who can solve problems creatively, learn how to learn, and think critically. So mathematics teachers need to know the update knowledge of mathematics and to know how to use the technology to present the subject matter in the class. For these reasons, last two decades had very busy schedule for many researchers to attempting to define the nature and the components of teacher knowledge that are necessary especially for mathematics teaching with the above skills. According to Koehler and Mishra (2008), good and effective teachings with technology have three core components: first is technology second is pedagogy and third component is content with the relationships between them[4]. The composition of these three terms is known as *Technological Pedagogical Content Knowledge* (TPCK). The notion of technological pedagogical content knowledge (TPACK) had emerged in the literature of education journal in 2003 and in 2005, several seminar articles have been published by the original acronym TPCK, the acronym has recently been changed to TPACK for the ease of pronunciation. Since 2005, TPACK has been a burgeoning focus of research. Hence the main aim of this study is to consolidate the emerging trends, concept and issues related to *Technological Pedagogical Content Knowledge* (TPACK) and how much it is useful for mathematics teachers for making effective teaching.

What is TPACK?

Technological Content Knowledge (TPACK) has been derived from the Shulman's concept of pedagogical content knowledge which highlights the importance of pedagogical content knowledge (PCK), subject matter knowledge (SMK) and curricular content knowledge (CCK) and their complex relationships about how a teacher need to present knowledge with the help of PCK and CCK and how these knowledge helps to make meaning full teaching, and diagnosing the misconception of the students in specific topics. Similarly TPACK also emphasise the teaching to making effective and understandable. According to Koehler & Mishra (2008), TPACK emphasise the comprehensive set of competencies teachers need to successfully integrated technology in their educational practices. It is intersection between the technology, pedagogy and content knowledge. As technology, students, teachers, and classroom contexts change, TPACK provides a dynamic framework for viewing teachers' knowledge necessary for the design of curriculum and instruction focused on the preparation of their students for thinking and learning mathematics with digital technologies. The TPACK is proposed as the integration of multiple domains of knowledge in a way that support teachers in teaching their students the subject matter with technology. TPACK has consisted of seven different knowledge areas: (i) Content knowledge (CK), (ii) Pedagogical knowledge (PK), (iii) Pedagogical content knowledge (PCK), (iv) Technology knowledge (TK), (v) Technological content knowledge (TCK), (vi) Technological pedagogical knowledge (TPK). (See Figure)

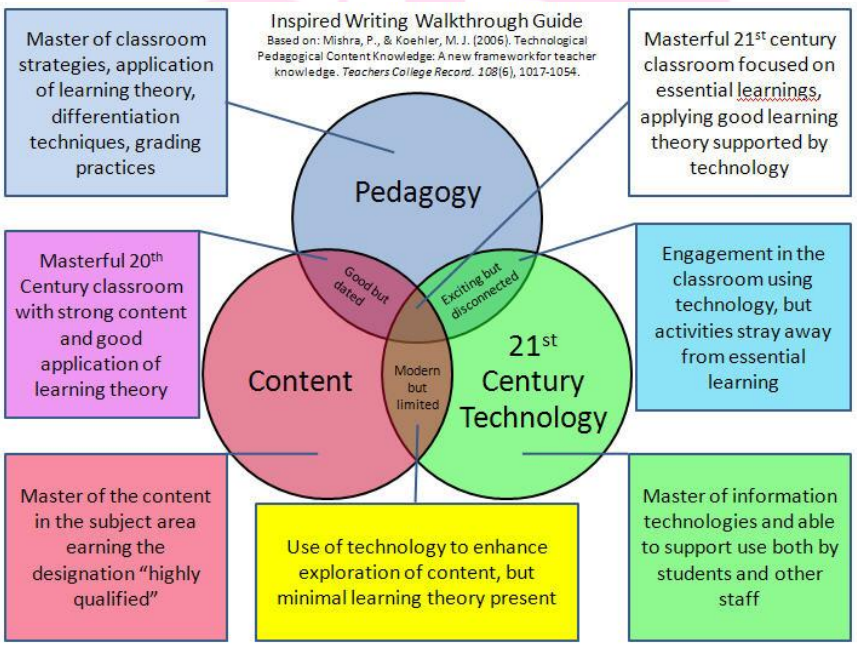

Figure 1: Framework of TPCK: (Kohler & Mishra, 2008)

(i) *Content Knowledge* (CK): Generally refers to subject matter knowledge that is, fact, concepts, theories, and principles that are taught and learned, rather than to related skills-such as reading, writing, or researching that students learn in academic courses. Content knowledge or subject matter knowledge is most important for mathematics as well as other subject teachers. Teachers who have strong subject matter knowledge give details in their lesson, link the topic to other topics, ask students many questions, and stray from the textbook.

(ii) *Pedagogical Knowledge* (PK): It referrers as knowledge of different method, strategies and learning theories. Pedagogy is the act of teaching together with its attendant discourse. It is what one needs to know, and the skills one needs to command in order to make and justify the many different kinds of decisions of which teaching is constituted. According to Shulman (1987), pedagogical knowledge refers as broad principles and strategies of classroom management and organisation that appear to transcend subject matter. Whereas S. Pamuk defined as 'general skills, beliefs, and knowledge related to teaching, independent of a particular subject area'.

(iii) *Pedagogical Content Knowledge* (PCK): It has formally emerged by Shulman in 1986 and he defined as "Pedagogical content knowledge identifies distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organised, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction (Shulman, 1987, p. 4)". Therefore, Pedagogical content knowledge (PCK) refers the knowledge of how to transform subject matter knowledge into meaningful learning outcomes for learners and it is included that an understanding of a specific topic and how teachers represent, explain or illustrate the topic or concepts to make sense to the learners in classroom and how they diagnose the student's misconceptions.

(iv) *Technological Knowledge* (TK): Technology knowledge (TK) includes knowledge of technologies which helps to teach such as books and chalk and blackboard, and advanced technologies such as the Internet and digital video, hardware, software and the different modalities they provide for representing information.

(v) *Technological Content Knowledge* (TCK): Technological content knowledge (TCK) refers to knowledge about how technology may be used to provide new ways of teaching content.

(vi) *Technological Pedagogical Knowledge* (TPK): Technological pedagogical knowledge (TPK) refers to knowledge about the affordances and constraints of technology as an enabler of different teaching approaches.

Therefore *Technological Pedagogical Content Knowledge* (TPACK) encompasses all six type of knowledge which has been described in above such as CK, PK, PCK, TK, TCK, and TPK. It can be also define as knowledge and understanding of the intersection between the PCK, TCK and TPK when using the technology for making teaching effective and interesting.

Developing a Mathematics TPACK

What does TPACK knowledge mean for mathematics teachers? Niess (2005) adapted Grossman's (1989, 1990) four components of PCK to describe teachers' knowledge of incorporating technology in teaching mathematics as the knowledge and beliefs teachers demonstrate that are consistent with:

- An overarching conception about the purposes for incorporating technology in teaching mathematics;
- Knowledge of students' understandings, thinking, and learning of mathematics with technology;
- Knowledge of curriculum and curricular materials that integrate technology in learning and teaching mathematics;
- Knowledge of instructional strategies and representations for teaching and learning mathematics with technologies.

Math Teachers' TPACK

Many mathematics teachers are aware of technological opportunities like interactive whiteboards, graphing calculators, dynamic mathematics software, graphing programs, computer algebra systems etc. and use them in their lessons. However the quality of ICT usage is not just using technology itself, but how the selected technology is integrated into a particular content with well-selected activities in the classroom settings. A teacher with efficient TPACK knowledge is assumed to know how to integrate these key technologies to a specific content with specific objectives applying the most suitable pedagogies. 21st century teachers are expected to know how to integrate the technology in every aspect of education like curriculum designs, implementation, management and evaluation (Jang S. J., Tsai, M. F., 2012). Hence it has the utmost importance for a teacher to be equipped with TPACK knowledge to survive in future's education system.

There are many countries started initiatives involving technology integration projects in their education systems like FATIH Project in Turkey. Many of those projects are based on only providing the technologies. Although they are aimed to have big impact on the education

systems, they do not have one as the professional development of in-service teachers are ignored. Since today's teachers main problem is that they learned mathematics in the past and mathematics can be taught as they learned (Niess, 2009), providing only technology cannot be enough for the desired integration. In order to want teachers to change their teaching ways using technology, professional development opportunities must be supplied to them (Waits & Demana, 2000; Bos & Lee, 2012). There should be ongoing support for teachers during the academic year. Throughout the ongoing support teachers should help each other by sharing their ideas about efficient technology integration (Niess, Lee, Sadri & Suharwoto, 2006). Since integrating technology in mathematics lessons is a kind of evolution of teaching mathematics, it needs time and experience for teachers to believe in mathematical power of technology (Bos & Lee, 2012). Niess et al. (2006) suggested school support and encouragement from others, access to computers, and more practice for successful support for teachers to improve their integration of technology.

Teachers should be careful while preparing and designing lesson plans. They should build up a lesson focused on the content not the technology itself. Because the main goal of a mathematics teacher is to teach the mathematics not the technology. By considering TPACK as the interaction of three components, the challenge here is the designing the lesson like a recipe of a soup. What should be the order and amount of three ingredients (T, P, C) to have a delightful soup? Is the order important during the recipe? The answers to those questions are important for a well-designed TPACK lesson plan. Let us think about the three components technology (T), pedagogy (P), and content (C) and assume that there are a, b, and c many different alternatives respectively. If we want to list all the possible lesson plans, there are a.b.c many lesson plans available theoretically by fundamental counting principle. However many of these lesson plans are waste. Therefore the important skill for a teacher is to decide which alternative(s) is appropriate for a particular content by selecting technology and pedagogy.

Mathematics Teacher, Teaching and TPACK

In modern time, digital technology has become essential part of our life and it is also left the impact on the children's mind. So it is incumbent upon teachers to encompass the modern technology for inculcating mathematical concept to the students. There are various topics in mathematics such as the topics of solid geometry, hydrodynamics, fluid dynamics, calculus, vector algebra etc left misconception in student's mind. So in this situation, modern technology could be inconceivable tool for the making these topics understandable or

explainable form. According to National Council of Teacher of Mathematics (NCTM) stating that "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (NCTM, 2000, p. 24). Similarly, the Association for Mathematics Teacher Educators (AMTE) had propounded a idea related to inclusion of technology in mathematics teaching and for enhancing the preparation of mathematics teacher with technology as "Mathematics teacher preparation programs must ensure that all mathematics teachers and teacher candidates have opportunities to acquire the knowledge and experiences needed to incorporate technology in the context of teaching and learning mathematics" (AMTE, 2006). Many researches have been conducted to know how to include the technology for teaching mathematics and what will be the framework for mathematics teaching. Niess, Sadri and Lee are the first who had been given the unconceivable model of mathematics teaching under the technological pedagogical content knowledge (TPACK). They reframed model for TPACK emanating from Everett Rogers' (1995) model of the innovation-decision process in terms of mathematics teachers learning to integrate a technology that they had not yet integrated in teaching and learning mathematics. They had propounded that teachers progressed through following five-stage developmental process when learning to integrate a particular technology in teaching and learning mathematics:

1. *Recognizing* (knowledge), where teachers are able to use the technology and recognize the alignment of the technology with mathematics content yet do not integrate the technology in teaching and learning of mathematics.
2. *Accepting* (persuasion), where teachers form a favourable or unfavourable attitude toward teaching and learning mathematics with an appropriate technology.
3. *Adapting* (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with an appropriate technology.
4. *Exploring* (implementation), where teachers actively integrate teaching and learning of mathematics with an appropriate technology.
5. *Advancing* (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning mathematics with an appropriate technology.

Above five categories has been resented as for integrating technology in teaching and learning mathematics on the basis of knowledge of technology, pedagogy and content knowledge. Further AMTE has presented the visual map of the category for thinking about the TPACK levels (See figure 2)

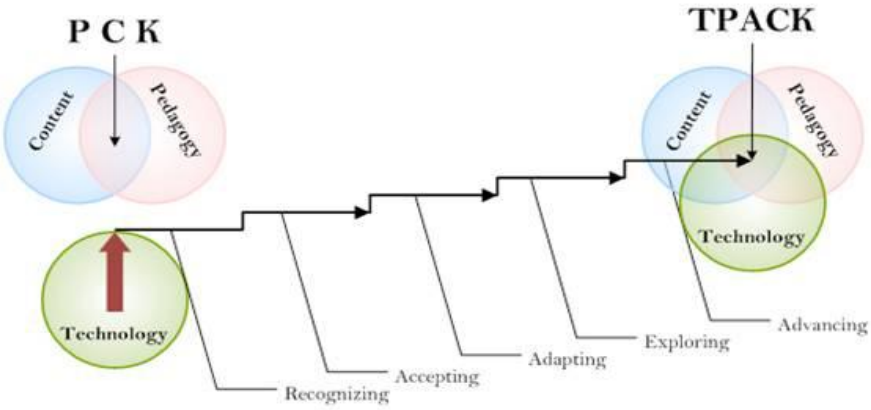

Figure 2. Visual description for thinking about TPACK level.

The above figure depicts levels in which teachers engage him with content, pedagogy and technology for the development of knowledge and understandings. Left side of the figure highlights that PCK as the intersection of content and pedagogy and then technological knowledge intersecting with PCK where teacher enable to guiding student learning mathematics with appropriate techniques and this knowledge and quality of teachers is known as teacher's technological pedagogical content knowledge that is TPACK, finally he got right hand side position which is indicating the TPACK as the intersection of content, pedagogy with technology.

Further AMTE developed the Mathematics Teacher TPACK Developmental Model in which four major themes has been included-such as Curriculum and assessment, Learning, Teaching and Access. The description of this model has been presented in table-1 in following.

Table-1: *Descriptors for Major Themes in the Mathematics Teacher TPACK Development Model*

Theme	Descriptions
Curriculum and assessment	Curriculum, the treatment of the subject matter Assessment, assessing the students' understandings
Teaching	Focus on subject matter (i.e., learning of mathematics topics) Demonstration of conceptions of how students learn (i.e., development of students' thinking skills)
Learning	Focus on subject matter (i.e., learning of mathematics

	topics) Instructional approaches Classroom environment Professional development
Access	Usage (whether or not students are allowed to use technology) Barriers (how teachers address barriers to technology integration) Availability (how technology makes higher levels and more mathematics available for investigation for greater numbers of more and more diverse students

Each level of this model has been completed going through the recognizing, Accepting, Adapting, Exploring and Advancing. This model may be very effective for developing mathematical concept by TPACK.

Challenges: Implementation of TPACK Model

Although TPACK framework provides a useful theoretical topography to explain how to integrate technology into teaching but implementation of that principle is not easy task. S. Pamuk had found in their study that creation of new knowledge based from interaction among core components (i.e. TPK, PCK, and TPACK) was one of the major challenges. Further he was explained that good technological backgrounds, lack of pedagogical experience and understanding of different teaching strategies are major issues in developing the TPACK knowledge base. As we know it that TPACK comprised three basic knowledge such as TK, PK and CK and other four derived from the intersection among these three basic sources and these becomes as 'technological content knowledge' (TCK), 'Pedagogical content knowledge' (PCK) and 'Technological pedagogy' (TPK) and 'Technological pedagogical content knowledge' (TPACK).

Therefore challenges for developing TPACK and successful implementation are many such as challenge to use TK, PK, and CK and developing knowledge and instructional material by intersection of their knowledge of three sources i.e. how to develop knowledge and understanding of using technology to implement teaching method, how to organise and represent the knowledge of subject matter knowledge with the help of technology, how to

gain or develop knowledge of teaching method and strategies or instructional material with respect to subject matter knowledge for successful teaching, and how to develop or organise or to make plan to teaching in class with subject matter by using the technology, these are major challenges for a teachers to implementation of TPACK model of teaching in their classroom. In addition to this, many developing countries like India, mathematics teacher's belief, attitude towards technology, insufficiency of technological resources, and dearth of appropriate training institutes are the most possible challenges for TPACK models of teaching.

Instead of these Indian primary schools is going through lots problem of technological resources, dearth of proper training institution, insufficient IT professional involvement in teaching, teachers attitude towards teaching. These problems generate challenges for developing framework based on TPACK model and towards implementation of this model in real situation in the class.

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