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# Development of Technological Pedagogical Content Knowledge in Teaching of Mathematics for the Pre-Service Teachers : A Strategy

**M**athematics plays a vital role in building up our civilization by connecting all the fields. It is an essential tool which is applied in many fields such as Physics, Chemistry, Biology, Medicine, Engineering and so on. In the scientific world, the credit of all the technical progress of science goes to progress of Mathematics. Mathematics, according to National Policy on Education (NPE – 1986), should be visualized as the vehicle to train a child to think, reason, analyze and articulate logically.

**T**he main goal of Mathematics education in schools is the mathematisation of the child's thinking. There are many ways of thinking, and the kind of thinking one learns in Mathematics is an ability to handle abstractions, and an approach to problem solving. As stated by the National Focus Group in their Position Paper on Teaching of Mathematics (2006); "Universalisation of schooling has important implications for Mathematics curriculum. Mathematics being a compulsory subject of study, access to quality Mathematics education is every child's right".

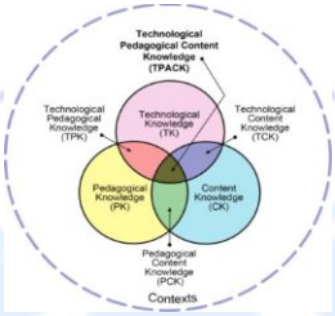
**O**n the other hand, Mathematics education in our schools is beset with problems. Due to hierarchy of concepts and largely deductive and abstract nature of the subject, Mathematics is considered as a very dull and difficult subject. No doubt, Mathematics is a subject which requires single-minded concentration and continuous efforts to achieve perfect and accurate learning. For this, it is necessary to make the involved abstractions tangible and concrete by developing the mathematical concepts out of direct personal experiences. Thus, by putting something concrete into the hands of students, will give a better picture of conceptualization of the problem. Hence, the traditional approach of teaching Mathematics in which abstract

concepts are usually presented to the students in an authoritarian way should be discouraged and newer approaches which stress the presentation of concrete experiences should be encouraged. This is undoubtedly based on presenter's ***'Pedagogical Content Knowledge'***. In fact, development of Pedagogical Content Knowledge among in-service teachers and pre-service teachers would be a challenging task for the Teacher Education system.

**C**onsidering Teacher Education system as a higher education stage, one can realize that the assumption: ***"Generalizations in Mathematics are formed inductively and applied deductively",*** is very true. But at the same time, having only the knowledge of applying the generalizations deductively in teaching of Mathematics will not serve the purpose of access to quality Mathematics education at school level, which is considered every child's right. To justify the efficacy of the above assumption, it is essential to have in-depth Pedagogical Content Knowledge among in-service teachers as well as pre-service teachers. Hence, development of Pedagogical Content Knowledge among pre-service teachers through different ways and means is the utmost demand especially in case of Teaching of Mathematics. Looking to this importance, the authors have employed a strategy named; ***"Development of Technological Pedagogical Content Knowledge"*** in Pre- service Teacher Education both at Primary and Secondary levels, as an integral part of the Teaching Method namely; "Teaching of Mathematics". The present paper focuses on the conceptual base of ***'Technological Pedagogical Content Knowledge' (TPACK)***, the strategy implemented based on the TPACK and its multi-dimensional impact on pedagogical skill development for the pre-service teacher trainees. The strategy is realistic since it envisages student teachers to disseminate these skills to the coming generations in schools and is also pragmatic and relevant in the context of quality based teaching of Mathematics. This endeavor can also be viewed as development of TPACK framework conceptually, theoretically and empirically.

**Technological Pedagogical Content Knowledge (TPACK)** :

**T**PACK is a framework that identifies the knowledge teachers need to teach effectively with the support of technology. It attempts to identify the nature of knowledge required by teachers for technology integration in their teaching, while addressing the complex, abstract and multifaceted nature of content categories.




As shown in the figure, TPACK framework is the complex interaction of three primary forms of knowledge namely; Content (CK), Pedagogy (PK), and Technology (TK). The TPACK approach goes beyond seeing these three knowledge bases in isolation. TPACK also emphasizes the new kinds of knowledge that lie at the intersections between them, representing four more knowledge bases for the teachers applicable to teaching with technology: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and the intersection of all three circles, Technological Pedagogical Content Knowledge (TPACK). (Koehler and Mishra, 2009)

Individual teachers, grade-level, school-specific factors, demographics, culture, and other factors ensure that every situation is unique, and no single combination of content, technology, and pedagogy will apply for every teacher, every course, or every view of teaching. Hence, effective technology integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic, transactional relationship between these components of knowledge with reference to contexts.

**Components of TPACK :**

According to Koehler and Mishra (2009), there are seven components of TPACK, which are described briefly as under;

- **Content Knowledge (CK)** : Teachers' knowledge about the subject matter to be learned or taught. This knowledge would include knowledge of concepts, theories, ideas, organizational frameworks, knowledge of evidence and proof, as well as established practices and approaches toward developing such knowledge.
- **Pedagogical Knowledge (PK)** : Teachers' deep knowledge about the processes and practices or methods of teaching and learning. They include, among other things, overall educational purposes, values, and aims. This basic form of knowledge applies to understanding how students learn, general classroom management skills, lesson planning, and students' assessment.

- **Technology Knowledge (TK)** : Knowledge about certain ways of thinking about, and working with technology, tools and resources. Working with technology means to apply all technology based tools and resources. This includes understanding information technology broadly enough to apply it productively at work and in everyday life, being able to recognize when information technology can assist or impede the achievement of a goal, and being able continually adapt to changes in information technology.
- **Pedagogical Content Knowledge (PCK)**: Knowledge of pedagogy that is applicable to the teaching of specific content. PCK is the notion of the transformation of the subject matter for teaching. Specifically, this transformation occurs as the teacher interprets the subject matter, finds multiple ways to represent it, and adapts and tailors the instructional materials to alternative conceptions and students' prior knowledge. PCK covers the core business of teaching, learning, curriculum, assessment and reporting, such as the conditions that promote learning and the links among curriculum, assessment, and pedagogy.
- **Technological Content Knowledge (TCK)**: It is an understanding of the manner in which technology and content influence and constrain one another. Teachers need to master more than the subject matter they teach; they must also have a deep understanding of the manner in which the subject matter (or the kinds of representations that can be constructed) can be changed by the application of particular technologies. Teachers need to understand which specific technologies are best suited for addressing subject-matter learning in their domains and how the content dictates or perhaps even changes the technology or vice versa.
- **Technological Pedagogical Knowledge (TPK)**: It is an understanding of how teaching and learning can change when particular technologies are used in particular ways. This includes knowing the pedagogical affordances and constraints of a range of technological tools as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies.
- **Technological Pedagogical Content Knowledge (TPACK)**: Underlying truly meaningful and deeply skilled teaching with technology, TPACK is different from knowledge of all three concepts individually. Instead, TPACK 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.

Based on the above conceptual framework, the authors were intended to get answers of the following questions empirically, in terms of studying the efficacy of the implemented strategy (i.e. Development of TPACK).

- Can TPACK be the basis of effective teaching of Mathematics with technology?
- Can TPACK be useful in getting an understanding of the representation of concepts using technologies?
- Can TPACK proved to be a useful pedagogical technique of integrating technologies in constructive ways to teach content of Mathematics?
- How technology under TPACK can help in redressing some of the problems that students face related to conceptualization in Mathematics?

**The Strategy: Development of Technological Pedagogical Content Knowledge :**

**D**uring the long experience of the authors as Mathematics teachers and teacher educators, they have felt the need of conceptualization in mathematical concepts for better learning. Usually, students feel difficulties in learning some of the concepts in Mathematics. Hence it is essential to identify constructive ways or pedagogical techniques to redress their difficulties and to make learning more effective and long lasting. For this, in-service teachers and pre-service teachers must have sound knowledge of content along with pedagogical and technological knowledge. Thus, focusing on this aspect authors have developed a strategy named; ***"Development of Technological Pedagogical Content Knowledge"*** with a view to achieve following objectives:

- To implement the strategy on pre-service teacher trainees (at primary and secondary level) for better conceptualization in Mathematics.
- To acquaint them about the pedagogical technique of integrating technologies in constructive ways to teach content of Mathematics.
- To study the efficacy of the implemented strategy empirically.

**Identification of the Mathematical Concepts :**

**B**ased on practical validity of the assumption: ***"Generalizations in Mathematics are formed inductively and applied deductively",*** the following mathematical concepts (mostly in the

form of generalizations) have been identified for the development of the said strategy. The identified mathematical concepts are mentioned in the following table

| Sr. No. | Name of the Concept / Teaching point with logical explanation |
|---|---|
| 1. | Multiplication of two negative numbers is positive |
| 2. | Value of $\pi$ |
| 3. | Identity: $(a+b)^2 = a^2 + 2ab + b^2$ |
| 4. | Identity: $(a+b+c)^2 = a^2 + b^2 + c^2 + 2ab + 2bc + 2ca$ |
| 5. | Formula : **No. of sub-sets of a given set** = $2^n$ , where n = no. of elements in the given set |
| 6. | Pythagoras Theorem : ($AC^2 = AB^2 + BC^2$ , for a given Right angle triangle) |
| 7. | Logical explanation of "Anything rest to zero is equal to one (i.e. $2^0 = 1$ )" |
| 8. | Logical explanation of " $1 / 0 = \infty$ " |
| 9. | Logical explanation of the Formula : Area of a Rectangle : $A = l \times b$ |
| 10. | Logical explanation of the Formula : Area of a Circle : $A = \pi \times r^2$ |
| 11. | Logical explanation of the Formula : Volume of a Sphere : $V = 4/3\ \pi \times r^3$ |
| 12. | Logical explanation of Euler's Formula for Regular Polyhedron (Platonic Solids) : $V - E + F = 2$ |

**Selection of Technological Pedagogical Content Knowledge :**

A set of various technology based content appropriate to the above selected concepts has been selected from the already prepared or available e-resources. While selecting this Technological Pedagogical Content, following criteria have been considered;

- It should have relevance with the selected concepts.
- It should be a proper combination of visuals, animations, picture slides, figures, PPTs etc. for the concept clarity.
- It can be further facilitated through laboratory approach, if necessary.

**Implementation of the Strategy :**

The strategy was implemented in two Pre-service Teacher Education Institutions during the academic year 2013-14. The detail of the included pre-service teacher trainees in this experiment is given as under:

| Sr. No. | Name of the Institute | Catering Pre-service Teacher Education | No. of pre-service teacher |
|---|---|---|---|

| | | at.. | trainees included |
|---|---|---|---|
| 1. | District Institute of Education and Training, Karelibaug, Vadodara | Primary level | 22 |
| 2. | Department of Education, Faculty of Education and Psychology, The M. S. University of Baroda | Secondary and Higher secondary level | 35 |

**I**mplementation of the strategy was scheduled in the regular time-table of Method classes of 'Teaching of Mathematics', while teaching a unit entitled: ***"Various Methods/Approaches for Teaching of Mathematics".*** Under the said strategy, a collection of selected animations, audio-visuals and PPTs were presented for conceptualization of the selected mathematical concepts. They were followed by discussion with the trainees for further clarification. The trainees were also facilitated by using laboratory approach in case of some of the concepts for more clarification, where it was found necessary.

**Evaluation :**

**W**ith a view to study the efficacy of the implemented strategy empirically, the trainees were assigned different task as a part of their assignment or practical work. They were also encouraged to prepare and implement such kind of strategy, focusing on any difficult concept in Mathematics during their practice teaching phase. A type of qualitative evaluation and measurement done was based on observation and performance assessment. Since the empirical evidences in this case were in terms of the quality of their assigned task and instructional process during practice teaching phase, it was observed that most of the trainees have put their fullest efforts in this regard. It was also observed that the trainees had focused on various mathematical competencies like formal problem solving, use of heuristics, estimation and approximation, use of patterns, reasoning and proof, making connections, measurement, visualization of the concepts/abstractions, conceptualization, analogy, critical thinking, creative thinking, logical thinking, using rules of thumb, manipulation, experimentation, doing recreational activities, drawing figures / graphs, demonstrations etc. in their work related to assigned task along with the pedagogical knowledge.

**Conclusion:**

**I**t seems that a paradigm shift from mathematical content to creation of mathematical learning environment has made a difference. It also facilitates the competencies based on 5E' Learning cycle [Engage, Explore, Explain, Elaborate and Evaluate] for the pre-service

teachers. Giving importance to processes under this strategy can prove it a multi-dimensional approach. At the same time, a great deal needs to be done towards preparing teachers for Mathematics education. A large treasury of e- resource material, which pre-service teachers and in-service teachers can access freely as well as contribute to, is badly needed.

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