REIMAGINING COURSE DESIGN USING TECHNOLOGY A CASE-STUDY OF HOW FACULTY IN INDIA LEARN TO INTEGRATE TECHNOLOGY TOOLS INTO ENGINEERING COURSES

by

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To Mom and Dad,

For guiding me all the way

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ABSTRACT

Author: Kandakatla, Rohit, R. PhD
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Title: Reimagining Course Design using Technology: A Case-Study of How Faculty in India Learn to Integrate Technology Tools in Engineering Courses.
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In the last two decades, higher education researchers have reported numerous benefits of integrating technology tools in course instruction and their subsequent impact on the students' learning process. In spite of the accumulation of the large amount of evidence and multiple calls to adopt technology tools in instruction, traditional lecturing is observed to dominate and continue being the preferred mode of instruction in STEM courses. One of the major reasons for the shortage of large-scale adoption of technology-based instruction is attributed to the lack of knowledge and skills of STEM instructors on how to effectively integrate technology tools into their courses. Most faculty development programs that are organized to help instructors build the necessary knowledge and skills end up introducing different technology tools to the instructors without truly helping them understand how to contextualize the tools based on the course requirements and learning needs of the study. This study aimed to understand the experiences of how engineering faculty in India learn to integrate technology tools as part of a 6-week faculty development program.

Seven engineering faculty from a single institution attended the 6-week program to redesign a course of their choice by integrating educational technology tools. A conceptual framework called Technological Pedagogical Content Knowledge (TPACK) was used to understand how the instructors learned to integrate technology tools into their respective courses. TPACK is a widely used framework that depicts an instructor's knowledge of educational technology as a multifaceted construct that is combined with their knowledge of the course content and pedagogy. A qualitative case study approach was used in this study to understand how the engineering faculty developed TPACK and highlight the challenges that they encountered while integrating technology tools into their courses. Thematic analysis was employed to analyze the data that was collected through semi-structured interviews, reflection journals, and final reflections.

The findings from the study indicate that the faculty developed TPACK in three stages. In the first stage, they developed basic knowledge of content, pedagogy, and technology (also called basic sub-domains of TPACK). The faculty in the next stage formed mental models to intersect and understand the interrelations between the three basic sub-domains. In the last stage, the faculty developed TPACK by building a meta-conceptual awareness of how to utilize the knowledge gained in stage two to address the limitations in their current mode of instruction and the learning needs of the students. It was observed that the faculty after developing TPACK started to emphasize on a more student-centric mode of instruction. The faculty reported to encounter challenges while constructing mental models as they were unable to critically reflect on their courses. They faced difficulty while identifying and integrating technology tools as a result of low-technology self-efficacy. Faculty reported to overcome these challenges and receive support from the other participants as a result of a community of practice that was established prior to the start of the faculty development program. The study at the end provides recommendations to faculty developers on how to design and facilitate effective workshops that are aimed to help instructors integrate technology tools. A model which was developed from the findings of the study is provided to promote large scale integration of technology-based instruction in universities.

CHAPTER 1 - INTRODUCTION

1.1 Technology Adaptation in Higher Education

The utilization of technology in higher education has become an emerging trend in the last two decades. Universities have started to invest heavily in digital infrastructure that will transform their campus and accelerate the learning of the students. The Ohio State University, for example, has recently launched a Digital Flagship initiative where each of the incoming freshmen was provided with an iPad Pro that they will be using to progress through their program (Booker, 2018). The majority of higher education universities have begun to make use of Learning Management Systems (LMS) that would help instructors to develop, distribute, and manage their courses through open-source, proprietary, or cloud-based platforms (Dobre, 2015). A large number of universities have started to offer Massive Open Online Courses (MOOCs) and Small Private Online Courses (SPOCs) with a goal to provide students access to distance learning opportunities and support lifelong learning (Kaplan & Haenlein, 2016).

The integration of technology in higher education instruction is further supported by the ongoing emphasis on deep learning approaches. Deep learning approaches are pedagogical strategies that engage students in collaboration, critical thinking, problem-solving, and self-directed learning. Prior research indicates that the usage of technology in instruction has positively impacted the performance of the students (López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011) and helped them in building critical thinking and problem-solving skills (Yagci, 2016). The 2017 NMC horizon report indicated that the growing focus of blended and collaborative learning would drive the adoption of technology in higher education for the next few years (Adams Becker et al., 2017). This prediction is supported by the well-researched and understood benefits of blended and collaborative pedagogies and their impact on students learning. Many findings on the impact of blended learning suggest an increase in creative thinking, independent study, and the ability for the students to tailor learning experiences to meet their individual needs (Ellis, Pardo, & Han, 2016; Vo, Zhu, & Diep, 2017). The affordances that blended learning offers has been observed to support learning both inside and outside of the classroom (Gedik, Kiraz, & Yaşar, 2012). Instructors at Purdue University utilized technology tools to combine the blended and collaborative pedagogies in a core undergraduate engineering course that resulted in a drop in the number of students who received the non-passing D, F, and W grades (DeBoer et al., 2016; Rhoads, Nauman, Holloway, & Krousgrill, 2014). In view of the convenience and flexibility offered by blended learning designs, the statement on the Review of Modernization of Higher Education Systems in Europe (released at the 2016 Conference of European Schools of Advanced Engineering Education and Research) recommended the use of technology as a means to expand access to institutions (Adams Becker et al., 2017). The use of technology would also support the changing demographics of students in higher education where students are now looking for flexibility to attain a degree while supporting themselves through part-time or full-time jobs (Friedman, 2016).

1.2 Statement of Problem

In spite of the availability of a large body of evidence and the numerous calls on the need to adopt and utilize technology tools in instruction, traditional lecturing continues to be the predominant mode of instruction for STEM courses (Stains et al., 2018). This could be attributed to the lack of knowledge and skills of STEM instructors on how to effectively integrate technology into their course instruction. Faculty who tend to be subject matter experts often become comfortable with teaching content in a particular way and therefore resist to change their teaching practices (Johnson et al., 2013). Other factors that impede the adoption of technology in instruction include the amount of time required to learn about new technologies, beliefs that technology might not be relevant for teaching and learning, and limited technical skills. Additionally, replication of technology tools from one context and directly applying it to another has been considered to be largely ineffective (Evenhouse et al., 2017; Fullan, 2009). The use of technology tools in instruction must therefore be tailored depending on the learning objectives and needs of the learners in the course.

Instructors who are interested to implement technology in course instruction end up not having the necessary quality training that is required to revamp their courses using technology tools (Waldner, Widener, & McGorry, 2012). Higher education institutions, to support the growing calls for use of technology in course instruction, have started to provide their faculty with the necessary skills on how to utilize educational technology through faculty development programs (Sorcinelli, Austin, & Eddy, 2006). While the focus of the programs has been to prepare the faculty to teach with different educational technologies, a majority of the faculty developers treat the knowledge of technology as an independent entity (Mishra, 2006). Universities that are promoting the use of technology in courses conduct professional development programs that are facilitated by information technology (IT) staff, who do not know how to contextualize and implement technology tools based on the individual requirements of a course (Koehler, Mishra, & Yahya, 2007). This approach of merely introducing faculty with different educational technologies without any emphasis on how they should be used or integrated with the course content has given rise to challenges among faculty as they start to use technology in their courses (Mishra & Koehler, 2003). Prior studies indicate that the lack of proper integration of technology tools could result in an increase of cognitive load on students in the course (So & Brush, 2008). With the growing need to adopt technology-enhanced teaching, faculty development programs should help instructors develop the essential knowledge of how to teach with technology by situating the knowledge in the context of operation (Joan Hughes, 2005; Lundeberg, Bergland, Klyczek, & Hoffman, 2003; Margerum-Leys & Marx, 2000).

1.3 Purpose of Study and Research Question

Instructors' knowledge of how the different technology tools are integrated into the courses has become a major focus of research. Graham et al. report that the knowledge related to the effective integration and use of technology tools has become widely recognized as a critical aspect of an instructor's knowledge-base in the 21st Century (Graham et al., 2009). Additionally, the need for faculty development on technology-enhanced instruction has become an emerging trend in many of the developing countries. For example, the All India Council for Technical Education (AICTE) which is the highest regulatory body of technical education in India has recently announced to make teaching certification a mandatory pre-requisite for all engineering faculty in India. They recommended an eight module certification where one of the module is focussed on adapting new technologies and tools into their instruction. The mandatory teaching certification would entail faculty from more 3500 engineering colleges to undergo extensive training in order to be qualified as an engineering instructor in India. Such large scale professional development efforts would require faculty developers to have a good understanding of how to design and facilitate programs that would help instructors to adopt technology tools into their courses. A useful framework to understand technology integration into courses was developed by Mishra and Koehler, who described the instructor's knowledge of educational technology as a multifaceted construct with a combination of pedagogy and content. They named this conceptual framework as Technological Pedagogical Content Knowledge (TPACK). With TPACK, Mishra and Koehler believed that the instructors' knowledge of technology should be a balanced mix of technology, pedagogy, and content, which will ensure the effective integration of technology into their courses.

In this study, I design and facilitate a 6-week professional development program that would help engineering faculty in India learn to integrate technology tools into their respective course. The purpose of this study was to use the TPACK framework to examine the experiences of the engineering faculty in India as they combine the knowledge of content, pedagogy, and technology to redesign their courses and adopt to a technology-enhanced teaching approach. I address the following two research in the study:

1. How do faculty describe the development and using the various constructs of TPACK during the professional development experience?
2. What are the major challenges that the faculty encountered while integrating technology tools during the 6-week program?

1.4 Scope of the Study

This study captured the collective experiences of seven Indian engineering faculty who participated in the 6-week professional development program and redesigned their courses by integrating technology tools into the course instruction. All the faculty taught undergraduate engineering courses at an engineering institution in India where the professional development program was conducted. The study was qualitative in nature as it aimed to understand the phenomenon of development of TPACK in a professional development setting and did not attempt to generalize the findings to all engineering faculty in India.

1.5 Dissertation Organization

The dissertation is organized into five chapters. Chapter one introduced the research study by providing the rationale and motivation for conducting and addressing the two research questions of the study. Chapter two provides a literature review of the conceptual framework used in the study along with its application in cross-national and professional development context. I present an overview of engineering education in India and highlight the gaps in literature. Chapter three details the methods used to design and conduct the study, including the participant selection, participant information, data collection, and data analysis. Chapter four presents the results from the thematic analysis that emerged from the data. Chapter five concludes the study by discussing the themes in relation to the research questions, implications and recommendations for faculty developers and higher education universities, and the limitations of the study.

CHAPTER 2. REVIEW OF LITERATURE

2.1 Introduction

In this chapter, I review the existing literature associated with the Technological Pedagogical Content Knowledge (TPACK), which is the conceptual framework that is being applied to understand how the faculty learn to integrate technology tools into their instructional practice. I discuss prior literature to provide a chronological account of the development and utilization of TPACK and identify a research gap for need to further explore the development of TPACK as part of a professional development program that is situated in the higher education context. I also provide a historical account of the development of engineering education in India to highlight the cultural implications at the site of the study.

2.2 Technological Pedagogical Content Knowledge (TPACK)

Before we look at the literature on the TPACK, I first present the initial studies that focussed on Pedagogical Content Knowledge (PCK), which was used as the foundation for the development of TPACK.

2.2.1 Pedagogical Content Knowledge (PCK)

TPACK is an enrichment of Shulman's Pedagogical Content Knowledge (PCK), which is necessarily the overlap of an instructors' Content Knowledge (CK) about the subject and Pedagogical Knowledge (PK) (Shulman, 1986). Shulman argued that acquiring the knowledge of subject matter and basic pedagogical strategies does not make an individual a good teacher. He identified PCK as the most useful way to represent and formulate the content which will make it comprehensible for the learners. With PCK, instructors would develop an understanding of what makes the learning of specific concepts easy or difficult and of the preconceptions that students of different ages and backgrounds bring with them to the classroom. Grossman in her study later expanded the PCK construct that was introduced by Shulman and reported PCK to comprise of four central components: 1. Knowledge and beliefs about teaching a particular subject at different grade levels, 2. Understanding of difficult and important topics in the subject, and awareness of students' prerequisite knowledge in the subject, 3. Knowledge of instructional strategies to teach a particular topic in multiple ways, and 4. An understanding of horizontal and vertical curricula for a subject (Grossman, 1990). She defined horizontal curricula as the content and skills being learned by students in other subjects at the same time, and vertical curricula as an understanding of the subject being taught at different grade levels. Having the knowledge of the horizontal and vertical curriculum would allow a teacher to find connections between the different subjects being taught, and maintain continuity in the topics of a particular subject as the student progresses to a higher-grade level. In her expanded definition, Grossman looked at PCK beyond the knowledge to teach a specific subject and included an holistic understanding of the how the content is related to other subject of the curriculum.

2.2.2 Historical development of TPACK

The first study that proposed to include the knowledge of technology to PCK was conducted by Pierson as she evaluated how teachers with different years of experience used technology in their teaching practice (Pierson, 2001). She claimed that the meaningful use of technology in a course can only happen when the teacher views technology usage as an integral part of the learning process. Peirson believed that a teacher who could effectively integrate technology would be able to extensively draw on their content and pedagogical knowledge in combination with technological knowledge. She defined the intersection of these three knowledge areas as Technological-Pedagogical-Content knowledge (TPACK).

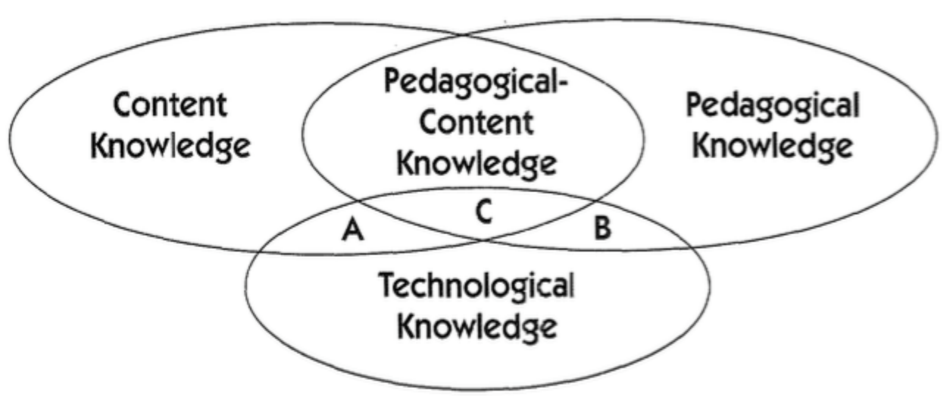

Figure 1 – Relationships between Content, Pedagogical, and Technological knowledge (Pierson, 2001).

Figure 1 represents the relationship between the types of teacher knowledge as reported by Pierson. Section A represents knowledge of content-related technology resources, section B represents knowledge of methods to manage and organize technology resources, and section C represents the intersection of technological-pedagogical-content knowledge (also defined as "true technology integration"). The study revealed that only teachers with extensive prior teaching experience were able to effectively integrate technology into their instruction.

Later, Margerum-Lays in her study explored the knowledge of how to efficiently utilize instructional technology in classrooms (Margerum-Leys, 2001). She examined the knowledge of educational technology through the lens of content knowledge, pedagogical knowledge, and Shulman's pedagogical content knowledge. She defined content knowledge of educational technology as knowing how to use technological tools, their affordances, and general Information and Communications Technology (ICT) technical skills such as troubleshooting and file management operations. The study defined PCK of educational technology as the knowledge that is derived from, and applicable to, teaching and learning situations involving educational technology. Teachers were said to possess "Pedagogical Content Knowledge of Technology" if they knew how to envision potential student problems with using technologies and configure instruction and learning tasks for a variety of technological tools.

A few years later, with the increase in the use of ICT tools, Angeli and Valanides suggested a framework called ICT-related PCK that limited the scope of educational technologies to ICT tools. They developed an instructional systems design model that could be used in teacher professional development courses to develop ICT- related PCK (Angeli & Valanides, 2005). They indicated that instructors who possess ICT-related PCK should know how to: 1. Identify topics to be taught with ICT in ways that signify the added value of ICT tools, such as topics that cannot be easily comprehended by students. 2. Identify ways to transform the content to be taught into different forms that are easily understood by students and difficult to support by traditional teaching. 3. Identify teaching strategies that are difficult to be implemented using traditional means, such as the application of concepts into contexts where it is not possible to be experienced in real-life, interactive learning, authentic learning, and adaptive learning to meet the needs of the learner. 4.

Select ICT tools with built-in features to afford content transformations and support teaching strategies, and 5. Infuse ICT activities in the classroom. The instruction systems design model was aligned to help the instructors build the different ICT-related PCK skills and ensure the effective utilization of ICT tools in their instructional practice.

At the same time when ICT-related PCK was introduced, Niess reported that the term pedagogy did not take into account the instructor's knowledge of the curriculum and the learners. She therefore replaced the term pedagogy with "teaching and learning" and defined TPACK as the intersection of content, technology, and teaching and learning (Niess & Garofalo, 2005). The rationale behind use of teaching and learning is in line with Grossman's expansion of the PCK construct where she believed an instructor should have knowledge of the vertical and horizontal curricula of the subject. By including teaching and learning in the framework, Niess reported four central components of TPACK: 1. An overarching conception about the purposes of incorporating technology in teaching, 2. The knowledge of students' understandings, thinking, and learning with technology, 3. Knowledge of curriculum and curricular materials that integrate technology in learning and teaching, and 4. Knowledge of instructional strategies and representation for teaching and learning with technologies. When compared to ICT-related PCK, Niess described TPACK as a body of knowledge rather than set of skills that could be developed to effectively teach with technology.

2.2.3 TPACK as a conceptual framework

Building upon prior research studies, Mishra and Koehler introduced TPACK a conceptual framework that includes technology as a third domain of knowledge, along with pedagogy and content. Similar to the initial study of Pierson, they developed a visual representation that depicts TPACK as the complex interrelation of a teacher's technology use, instructional methods, and understanding of the subject matter (Mishra & Koehler, 2006). Mishra and Koehler, in agreement with Neiss, defined TPACK as a body of knowledge and believed that a teacher who possesses TPACK would be able to use technology to represent content in a way that is best understood by students and adapt the pedagogy catering to the diversity of the students' background. However, TPACK as a conceptual framework was expected to be dependent and vary based on the context of operation as shown in Figure 2. The focus on context suggests that the TPACK of a secondary level science teacher would be different when compared to the TPACK of an undergraduate STEM instructor. For example, undergraduate STEM instructors might utilize their TPACK to develop technology-mediated resources that would enable students to self-regulate their learning process. The same cannot be said about secondary level science teachers whose students might not be able to use the resources by themselves outside of the class. Students in K-12 might need additional scaffolding and support to make them understand how the utilization of the resources would help them succeed in their courses.

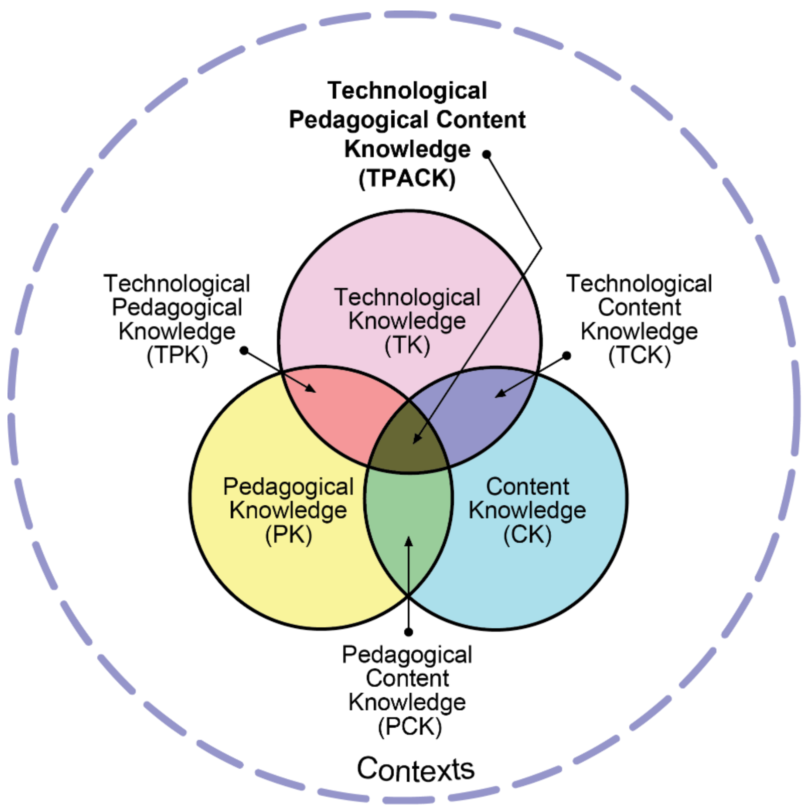

Figure 2 Representation of the multiple constructs of TPACK (Koehler & Mishra, 2009)

The conceptual framework of TPACK distinguishes itself from prior studies by looking at the relationship of content, pedagogy, and technology in pairs: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TCK), and all three combined together as Technological Pedagogical Content Knowledge (TPACK). It is important to note that each of the constructs are interlinked with each other and an individual is said to have TPACK only when they possess all the three together and not in isolation. Similar approach was taken by Shulman while he intersected the knowledge of content and pedagogy to form pedagogical content knowledge (PCK). However, the studies listed prior to Misha and Koehler reported TPACK by combining knowledge of technology (or ICT) with PCK and did not focus on the intersection between content and technology and technology and pedagogy. The description of each construct in the framework is provided in Table 1 as described by Mishra and Koehler.

Table 1 – Description of each construct in the TPACK framework (Mishra & Koehler, 2006)

Construct	Description
CK	"Content knowledge (CK) is knowledge about the actual subject matter that is to be learned or taught……including knowledge of central facts, concepts, theories, and procedures within a given field; knowledge of explanatory frameworks that organize and connect ideas; and knowledge of the rules of evidence and proof (Shulman, 1986)" (p. 1026)
PK	"Pedagogical knowledge (PK) is deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims. This is a generic form of knowledge that is involved in all issues of student learning, classroom management, lesson plan development and implementation. It includes knowledge about techniques or methods to be used in the classroom; the nature of the target audience; and strategies for evaluating student understanding." (p. 1026–1027)
PCK	"PCK is concerned with the representation and formulation of concepts, pedagogical techniques, knowledge of what makes concepts difficult or easy to learn, knowledge of students' prior knowledge, and theories of epistemology. It also involves knowledge of teaching strategies that incorporate appropriate conceptual representations in order to address learner difficulties and misconceptions and foster meaningful understanding. It also includes knowledge of what the students bring to the learning situation, knowledge that might be either facilitative or dysfunctional for the particular learning task at hand." (p. 1027)
TK	"Technology knowledge (TK) is knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video. This involves the skills required to operate particular technologies. In the case of digital technologies, this includes knowledge of operating systems and computer hardware, and the ability to use standard sets of software tools such as word processors, spreadsheets, browsers, and e-mail." (p. 1027)
TCK	"Technological content knowledge (TCK) is knowledge about the manner in which technology and content are reciprocally related. Although technology constrains the kinds of representations possible, newer technologies often afford newer and more

Table 1 continued

	varied representations and greater flexibility in navigating across these representations. Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology" (p. 1028)
TPK	"Technological pedagogical knowledge (TPK) is knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies." (p. 1028)
TPCK	"TPCK is the basis of good teaching with technology and requires 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 and to develop new epistemologies or strengthen old ones" (p. 1029)

The descriptions of TPACK constructs listed in Table 1 would be later used in this study to qualitatively categorize the participants prior knowledge and identify the development of the various constructs during 6-week professional development program.

2.2.4 Elaborated model of TPACK framework

The conceptual framework of TPACK mentioned above provided definitions to articulate the core of each of the three new constructs i.e., technological content knowledge (TCK), technological pedagogical knowledge (TPCK), and technological pedagogical content knowledge (TPACK). However, the framework was widely critiqued due to lack of clarification on the boundaries between the three constructs. This made it difficult for individuals to categorize knowledge that would be considered to be at the borderline of two constructs. To address this issue, Cox and Graham provided an elaborated model of the TPACK framework to describe an instructor's knowledge of integrating technology into their course (Cox & Graham, 2009). They conducted a conceptual analysis to address the complexity of the interrelationships among the various constructs of TPACK and presented an elaborated definition. They defined TPACK as the "knowledge of how to coordinate the use of subject-specific activities (As) or topic-specific activities (At) with topic-specific representations (Rt) using emerging technologies to facilitate student learning" (p. 64). Subject-specific activities are pedagogical activities that might be unique to a specific discipline, for example inquiry-based learning or project-based learning. Topic-specific activities are activities that could help students understand a specific concept or topic. This could include demonstration, simulations, or experiments. Topic-specific representations are ways to represent a particular concept that is most appropriate or relevant to the learner. For example, illustrations, examples, models, or analogies.

As shown in Figure 3, the revised framework clarifies the boundaries of overlap between pedagogy, content, and technology. PCK in the new model includes the knowledge of subject-specific activities and topic-specific activities. TCK refers to topic-specific representations in the given content domain using appropriate technologies. TPK refers to the knowledge of general pedagogical activities that a teacher can engage in using emerging technologies. The model emphasizes the sliding nature of TCK, TPK, and TPACK, as all the three constructs would be equivalent to CK, PK, and PCK respectively without the use of technology.

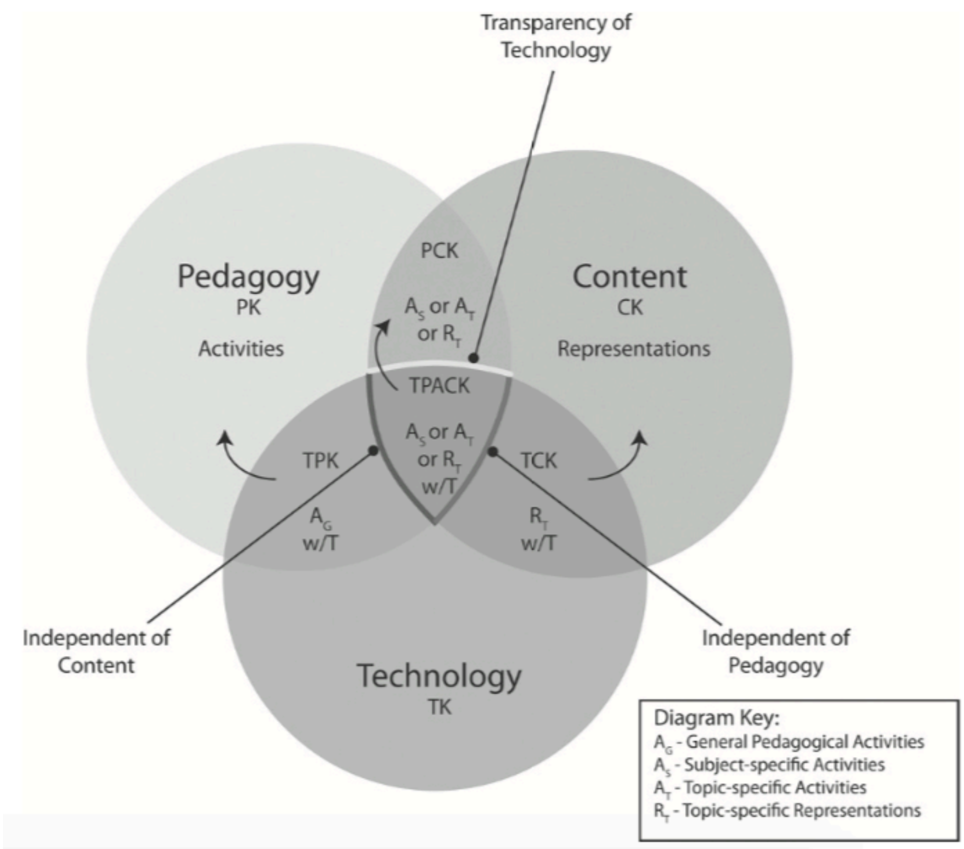

Figure 3 – Elaborated model of TPACK Framework (Cox & Graham, 2009, p. 63)

2.3 Development of TPACK

Now that we have established a conceptual understanding of the TPACK framework, I next review prior literature on the process of development of TPACK (the phenomenon of interest in this study). I present multiple studies that examined the development of TPACK from an epistemological and chronological perspective.

2.3.1 Epistemological considerations of TPACK

Angeli and Valanides in their work examined the epistemological aspects of TPACK to clarify the theoretical conceptualization of the construct (Charoula Angeli & Valanides, 2009). They specifically looked at whether TPACK is a unique body of knowledge that is constructed from the different sub-domains of TPACK (transformative view), or if TPACK is not a distinct form of knowledge and is integrated on the spot from the different sub-domains of TPACK while teaching (integrative view). Prior literature that took the integrative view approach reported that the growth in any of the sub-domains of TPACK automatically results in the development of TPACK (Hughes, 2008). However, the empirical investigations conducted by Angeli and Valanides refuted those claims and confirmed that the TPACK is not developed interactively. Their studies indicated that TPACK in itself is a unique body of knowledge and is constructed through the development of the various sub-domains of TPACK. To ensure the development of TPACK, instructors should be provided with multiple opportunities to transform their knowledge of the various sub-domains of TPACK into something new by taking the learners and context of operation into consideration (Krauskopf, Zahn, & Hesse, 2015). I therefore chose a transformative view to examine the development of TPACK and use a "learning by design" approach as part of the 6-wek professional development program to provide the faculty with enough opportunities to truly construct TPACK. Additional information about the learning by design approach is provided in the next chapter.

2.3.2 Process of development of TPACK

Koehler et. al. studied the experience of seven teachers who were designing online courses through a semester long seminar and characterized the process of developing TPACK into three stages (Koehler, Mishra, & Hershey, 2004). In the first stage, the participants focused on developing goals and outcomes of a course of their choice (emphasis was on the course content). The second stage involved broader concerns about issues of representation of course content and pedagogical strategies needed to facilitate the delivery of the content (emphasis was on TCK, PK and PCK). The pedagogical strategies involved the integration of technology through the development of a course website (emphasis was on TPK). In the third and final stage, the participants focused on integrating the different parts of the course development to ensure they fit together cohesively (emphasis was on TPACK). The three stages resonate with the transformative view which considers TPACK to be constructed using the various sub-domains of the framework. Olofson et al. suggested the development of TPACK to be a dynamic process and indicated two additional stages. They believed instructors, after the construction of TPACK using their prior knowledge and the basic sub-domains, should enact the knowledge in a specific context and continuously reflect on the enactment to shape their TPACK as an ongoing process (Olofson, Swallow, & Neumann, 2016). They defined this dynamic process as TPACKing, which requires the instructors to constantly update their knowledge by being aware of the latest trends in technology tools that are being utilized for educational purposes.

Gill and Dalgarno in their study conducted a longitudinal qualitative analysis to understand how pre-service primary school teachers developed TPACK during a four-year training program (Gill & Dalgarno, 2017). The study revealed that teachers' access to technology was critical to build their confidence in developing TPACK. The teachers reported that the opportunities provided to them to develop artefacts for the course helped while developing TPACK. Another study investigated the perception of pre-service elementary school teachers as they developed TPACK. Pre-service teachers were seen to pay attention to the goals of the course (CK), the factors that influence young children's development (PCK), and strategies to effectively integrate technology (TPACK) (Sancar Tokmak, 2015). The pre-service teachers encountered challenges while they integrated the basic sub-domains of TPACK, as most of the teachers viewed them as separate bodies of knowledge. It is however important to note that most of the studies mentioned in this section focussed on the experiences of teachers in the K-12 setting. This study therefore makes a unique contribution to the body of literature by examining the experiences of engineering faculty and shifting the focus on the development of TPACK to the higher education context.

2.4 TPACK in Higher Education and Cross-National Context

A majority of the studies mentioned in the previous sections on the conceptualization and development of TPACK were focused on pre-service and in-service teachers in K- 12. I now explicitly look for studies that applied TPACK to higher education and used the framework in cross-national contexts outside of the US.

2.4.1 TPACK in higher education context

There is currently limited literature available on how instructors experience the development of TPACK in the higher education context and especially in engineering education. Prior literature might not be completely translated to higher education as the TPACK framework is considered to be a unique body of knowledge that is constructed depending on the context of operation and the learning needs of the students (Koehler, Mishra, & Cain, 2013). Higher education students' approaches to learning, motivation, and cognitive strategies might differ when compared to the students in K-12. In their study, Heikkila and Lonka reported that students in universities are able to choose and adapt their learning strategies in a way that maximizes their chances of academic success (Heikkilä & Lonka, 2006). Students in higher education have also shown to exhibit self-regulated learning where they are able to set reasonable goals based on the expectations from the course or program and take responsibility over their learning (Wolters, Shirley, & Pintrich, 1996; Pintrich, 1999). The instructor's motivation and strategies for integrating technology tools might therefore be different for students in K-12, where the they are expected to provide additional scaffolding to ensure the learning of students in the course. Additionally, the demands of faculty in higher education are high when compared to teachers in K-12 as the faculty have multiple responsibilities apart from teaching their courses (Alvarez, Guasch, & Espasa, 2009). Faculty in higher education might therefore identify innovative ways to use technology that would reduce students' dependence on them and support self-regulated learning outside of the classroom. For example, faculty at Purdue Universities used technology tools to provide students with a suite of well aligned learning resources in a core mechanical engineering course that allowed the students to use a range of self-regulated learning strategies that supported their learning needs in the course (Kandakatla, Rhoads, Berger, & DeBoer, 2019).

There are only few studies that have used the TPACK framework in higher education. For example, Ioannis and Angeli proposed Technology Mapping as an approach to develop instructors' TPACK in Computer Science. Through Technology Mapping, computer science instructors were asked to map their of knowledge of technology tool affordances onto content and pedagogy to enable the development of complex and interrelated ideas between the affordances of technology and their PCK. Technology Mapping was introduced as a unique approach for faculty teaching computer science courses as they already had the knowledge about the affordances and constrains of various computer-based technologies. Similar to computer science, TPACK was applied to other contexts such as early childhood education (Tzavara & Komis, 2015) and mathematics education (Crompton, 2015). Considering that TPACK is a unique body of knowledge that is constructed based on the context of operation and the characteristics of the learners (Angeli & Valanides, 2009), the development of TPACK and the other constructs (TPK and TCK) might vary for higher education and engineering education in general. I therefore use the discipline of engineering as one of stratification parameter in the study to recruit faculty from different disciplines to examine difference in their experiences. It would be specifically interesting to compare the experiences of computer science (high computer-based technological knowledge) and non-computer science faculty and look at the differences in their approaches to integrate technology tools into their courses.

2.4.2 TPACK in cross-national context

The TPACK framework has been widely researched in the US and Canada and used across a few countries outside of North America. Koh and colleagues used a survey to measure Singapore pre-service teachers' perception of TPACK and pointed out the lack of culturally relevant TPACK survey instruments (Koh, Chai, & Tsai, 2010). They reported that Singapore teachers' attitudes towards technology which wasn't included in the TPACK survey had a significant influence on their perception of TPACK. Kabakci in their study developed TPACK instruments with instructors in Turkey who were experts in the field of educational technology (Kabakci Yurdakul et al., 2012) and did not report any cultural influence on the development of the instruments. Another study conducted with teachers in Colombia reported a significant correlation between the teachers' knowledge, self-efficacy of technology, and their TPACK (López-Vargas, Duarte-Suárez, & Ibáñez-Ibáñez, 2017). The same observation might also be relevant to the Indian context as the faculty attitudes and self-efficacy towards educational technology may vary widely depending on their prior experience with using education technology tools or technology in general. The availability of technology tools would also be critical while instructors develop TPACK and re-design their courses, as universities in many developing countries might not have the financial support need to provide all necessary technology tools. Due to its qualitative nature, the findings from this study might reveal other culturally relevant factors that might contribute to our understanding of the measurement and development of TPACK in India and other developing countries in general.

2.5 TPACK in Professional Development Context

I now present literature that used the TPACK framework in professional development settings and review best practice recommendations for designing programs that would facilitate the effective integration of technology tools into courses. Prior studies report that most of the TPACK professional development efforts in K-12 have separated the knowledge of content, pedagogy, and technology and treated the three as mutually exclusive domains of knowledge (Stover & Veres, 2013, Surry, 2010). Mishra and Koehler emphasized the need for thoughtful interweaving of the three sources of knowledge for an instructor to develop TPACK (Mishra & Koehler, 2006). While facilitating a semester long program, they used a "learning by design" that required a group of teachers to collaboratively work and design online courses (Koehler et al., 2004). Other professional developers reported to have used a similar approach where participants were expected to design a final product at the end of the professional development (Jaipal-Jamani & Figg, 2015a; Koh, Chai, & Lim, 2017; Polly, 2011). To facilitate the effective integration of technology, instructors should be provided with professional development opportunities that are embedded in classroom practices, include opportunities for reflection, and provide an authentic design experience (Matherson, Wilson, & Wright, 2014).

Jaipal-Jamani and Figg developed the framework of TPACK-in-Practice that maps the different TPACK constructs to actions that could be explicitly incorporated into a professional development context. They identified three components that were crucial to the transfer of an instructor's TPACK to their instructional practice: the interaction of Technological knowledge (TK) with Pedagogical Content knowledge (PCK), the interaction of TK with Content Knowledge (CK), and the interaction of TK with Pedagogical Content knowledge (Jaipal-Jamani & Figg, 2015b). Table 2 provides further information about each of the three components of TPACK-in-practice and lists the appropriate actions that are needed to bring the components into action.

Table 2 – The Components of TPACK-in-Practice (Jaipal-Jamani & Figg, 2015a)

Component	Characteristics and Examples of Teacher Actions in Practice
Technological Pedagogical Content Knowledge (TPCK-in-Practice)	Knowledge to match models of teaching appropriate for content to appropriate technology. Two characteristics supporting this are: 1. Knowledge of a Repertoire of Technology-Enhanced Activity Types such as WebQuests, spreadsheets, simulations to represent different Content Knowledge and skills. Teacher Action: to select most appropriate activity type to teach and represent the content learning outcome. 2. Knowledge of Content-based Models of Teaching such as inquiry or problem-based model appropriate for the technology- enhanced Activity Types. Teacher Action: select appropriate model of teaching for technology enhanced instruction
Technological Content Knowledge (TCK-in-Practice)	Knowledge to use content-appropriate technologies or cross-disciplinary technologies in instruction, and the personal competence to use these technologies to achieve specific subject matter goals or learning outcomes. Characteristics are: 1. Knowledge of content-appropriate technologies. Teacher Action: Match appropriate technology or repurpose technology to achieve content learning goals. 2. Competence with content –appropriate technologies. Teacher Action: Identify technical skills and personal competence for effective technology use.
Technological Pedagogical Knowledge (TPK-in-Practice)	Knowledge of practical teaching competencies (i.e., activity choices, organization, assessment, differentiation, classroom management) during planning and implementation of tech-enhanced lessons. Examples of some characteristics are: 1. Activity choices. Teacher Action: select technology-enhanced activity types based on content learning outcomes.

	Table 2 continued 2. Sequencing. Teacher Action: include technology and content skills into the lesson and unit. 3. Differentiation for technical competence. Teacher Action: introduce few technical skills in a lesson. 4. Modelling technology use to and for students. Teacher Actions: model technology use through teacher created exemplars and student modelling of skills in content examples.

The TPACK recommendations for professional development and the framework of TPACK-in-Practice were utilized in this study while designing the 6-week professional development program. Further details on the 6-week professional development program are provided in the next chapter.

2.6 Cultural Context of India

In this section, I present a historical overview of engineering education in India and highlight how the education landscape has transformed in the last two centuries. I also talk about the current professional development opportunities for engineering faculty in India to indicate the potential implications of the findings from this study.

2.6.1 Education system prior to British colonization

The education system across the Indian subcontinent prior to the British colonization depended on caste of the individual, which was divided into four categories – Brahmans, Kshatriyas, Vaishyas, and Shudras (Chauhan, 2008). The four castes were categorized based on the division of labor. The Brahmins, who are at the top of the hierarchy, are considered to be teachers, scholars, and priests and were taught about scriptures and religion. Next in hierarchy were the Kshatriyas who were responsible to protect the society from external threats and were therefore educated in various aspects of warfare. The Vaishyas were considered to be third in hierarchy and included traders who were responsible for the economy and supply of food. The Vaishyas caste therefore were taught about commerce and other specific vocational courses. The last in hierarchy were the Shudras who were primarily responsible to serve the upper three castes. The type of education that an individual received depended on their caste, which was decided based on the family in which they were born. The caste system as a result denied equal educational opportunities to the population as compared to the modern educational system, where students irrespective of their caste are prescribed a standard curriculum in the K-12.

2.6.2 Engineering education in India

The establishment of Indian Engineering Education took place during the British colonization of India in early 1800s. The British crown's takeover of the administration of the East India Company resulted in the inflow of technology in the form of railroads, roads, steam navigation, and telegraphs (Subramanian, 2015). The inflow of technology led to the establishment of engineering colleges that introduced India to the western educational system (Subramanian, 2010). The engineering colleges were established at various geographic locations as part of the Crown's goal to setup provincial education departments, voluntary schools, and universities (Whitehead, 2003). Most of the initial colleges established were focussed on Civil Engineering and were aimed to meet the developmental needs of the surrounding geographic areas. During India's struggle for independence, many other colleges were setup with the number rising from five in 1919 to twenty one in 1939 (B. Subramanian, 2015). The Indian Research Fund Association was established in 1911 to develop a structure and offer government and private research funding (Arnold, 2004). However in 1944, it was mentioned in a report on the state of industrial and scientific research in India that research carried out in India was cut off from the rest of the world, as the technical resources were not utilized for war purposes (as compared to other major countries). The conclusions from the report later provided motivation for engineering education reforms carried out in India post-Independence era.

Prior to India attaining Independence in 1947, the Sarkar committee recommended the establishment of four technical institutions (at four major geographic locations) along the lines of the Massachusetts Institute of Technology in the US. The committee emphasized the need for scientific training and recommended the inclusion of basic sciences, mathematics, and economics into the curriculum (Subramanian, 2015). Post-Independence, the Indian government setup four technical institutions named Indian Institute of Technology (IIT) that were declared as institutes of national importance. In the next few decades, the government also established multiple regional institutions named National Institute of Technology (NIT) to meet the technological and manpower needs of the region. However, the major expansion in Indian engineering education took place after the collapse of the Soviet Union. In 1991, the Indian government introduced major changes to their economic policies, one of them being the liberalization of the economy. The liberalization led to India becoming one of the fastest growing economies in the world, with the development of the IT and software sector being a key contributor to the growth. The growth in the IT and software section led to a huge increase in the number of engineering colleges from 157 in early 1980s to more than 3500 that were located across the different demographic regions of India (Subbarao, 2013). India in the last four decades, has as a result, observed a 400% increase in the number of engineering colleges (Pratik, Radhakrishnan, & Kandakatla, 2013).

While the increase in the number of IITs and NITs did contribute to this expansion, the major contributor to the increase was the private sector who established self-financing engineering colleges (Varshney, 2004). Most of the privately-owned engineering colleges are affiliated to a regional university and have limited or no autonomy on the curriculum and the assessment (*Affiliation Procedure and Regulations*, 2018). All of the engineering colleges in India are required to be accredited annually by the All India Council for Technical Education (AICTE). The AICTE, due to the exponential growth in the number of engineering colleges, could not monitor the quality of the institutions, and this as a result led to drastic deterioration in the standard of engineering education in India (Subramanian, 2015). Some of key contributors to the decline in quality include overcrowding of colleges in select geographic locations that resulted in an oversupply and shortfall of engineers in specific regions, lack of contextualization of curriculum to local technical needs, and maintenance of poor academic and teaching standards that resulted in unemployability of graduating students. A survey conducted by a private organization in India reported that 94% of Indian graduating engineers are not fit for employment in industries (Minds, 2016). While some academicians and industry leaders have refuted the high percentage, the actual number is still a concern for the Indian engineering education system.

To curb the declining standards the AICTE has mandated each institution to maintain a faculty student ratio of 1:20, and requires the appointment of one full professor, two associate professors, and 6 assistant professors for every nine faculty members (*Changes in Approval Process*

Handbook 2018 - 2019, 2018). While the AICTE requires every full and associate professor to hold a PhD in engineering, the qualification for the appointment of an assistant professor is only a bachelor's and master's in engineering. The massive growth of engineering colleges has led to a tremendous increase in demand for qualified engineering faculty in India, and most of the colleges therefore hire faculty immediately after the completion of their master's or PhD in engineering. Majority of the PhDs are trained to do research and end up graduating without any training in to teach engineering courses (Mohanty & Dash, 2016). The absence of any existing policies for pre-service and in-service training and lack of prior teaching experience (for assistant professors) is a key contributor to the decline in the quality of engineering education in India (Subbarao, 2013). A majority of the faculty upon start therefore possess only content knowledge in their specialized field of engineering without any training in pedagogy or using educational technology.

2.6.2 Professional development in India

The AICTE previously did not require the engineering faculty to have any pre-service or in-service training to teach engineering courses in India. There was also no mandated professional development offered to the faculty prior to the start of their teaching role. Most of the faculty therefore developed their teaching skills once they started to teach and incorporated innovative pedagogical techniques based on their motivation to help students learn better. However, the National Board of Accreditation (NBA) which grants accreditation to engineering schools in India requires faculty to regularly attend professional development programs to improve their teaching and technical skills (*Self-Assessment Report for Undergraduate Engineering Programs*, 2015). Most of the professional development workshops that are attended by faculty are as a result organized by the engineering colleges or universities in the region. The engineering college where the study is being conducted organizes 2-week faculty development workshops for all faculty prior to the start of the academic year (Tuti, Kandakatla, & Khamruddin, 2016). The workshops help faculty to organize their course structure and lesson plans, introduce them to active learning methodologies, and provide them an overview on how to conduct research in Scholarship of Teaching and Learning (SoTL).

The AICTE has very recently announced their vision to make faculty development mandatory for all individuals aspiring to teach engineering in India (Shinde, 2018). AICTE has recommended an eight module certification program that includes curriculum framework and adapting to new technologies and tools. As no prior work has been done by applying the TPACK framework to professional development in India, the findings from this study will help inform the development of robust professional development modules that will focus on the integration of technology tools into engineering courses in India. The inclusion of a multiple recommendations could enable the wide-spread dissemination of professional development modules across India (Dearing, 2009). The results could also be transferred to inform professional development in other developing nations that operate in a similar academic settings as India.

2.7 Role of Community of Practice in Professional Development

To design successful professional development sessions that will lead to sustainable and meaningful exchange of knowledge, professional developers have recommended the creation of a learning community among participants that will help them in assessing themselves and continuously make improvements (Loucks-Horsley, Stiles, Mundry, & Hewson, 2009). They recommended facilitators of professional development programs to establish a Community of Practice (CoP) prior to the start of the professional development program by seeking consensus from the group on participants. The CoP can then foster meaningful exchange of ideas and information through commonly agreed activities as part of the professional development program. The CoP model has been used by multiple individuals to support their professional development activities both in K-12 and higher education (Power et al., 2018; van As, 2018).

A Community of Practice (CoP) consists of a group of people who share a concern or passion for the work they do and learn how to do it (better or differently) by regularly interacting with other members of the CoP (Allee, 2000; Wenger, 1998). As compared to a social network, a CoP is differentiated by its three distinctive characteristics: 1. A Domain – an identified shared purpose or value among the members of CoP, 2. A Community – a group of people who are interested in pursuing the domain and engage in joint activities to share information and help each other, and 3. A practice – a set of ideas, initiatives, resources, and tools that the members of the CoP share as a part of their membership (Wenger, 2011). CoPs take on multiple forms: they can be located at the same place or distributed across a geographic region, they can cease to exist after the short-term or long-term goal is achieved, the domain of interest could be homogenous or heterogeneous, they can be housed within a single organization or spread across multiple such units, and they can be informal or recognized officially by organization. While forms of CoPs can differ, the current literature mostly reports on ones that emerge within an organization, and often involve a community of members who are already working with one-another (Wenger, 2011). The key activity of a CoP is to advance its domain, which is the focus of the community. The domain defines the identity of the community, which sets the tone for developing the shared resources for practice. The community operates through multiple ways such as sharing information, problem solving, learning from experts from outside the CoP, and visiting individuals from different organizations or COPs (Wenger, McDermott, & Snyder, 2002).

Individuals who are part of the CoP would get diverse perspectives of the topic of interest when they collaborate and engage in group work (Donnelly & Maguire, 2018). Carter in her work suggested that individuals in a CoP to be assigned to a critical friend whose role would be to probe questions and help the individual gain new insights about the topic (Carter, 2009). This would be particularly beneficial to individuals who might have trouble reflecting and might need the probing question to think critically. CoPs formed in the same workplace will facilitate informal discussions among individuals outside of the professional development sessions and help sustain interest about the topic (McArdle & Ackland, 2007). Online CoPs can also be established to expand and sustain large scale professional development efforts (Vavasseur & MacGregor, 2008).

After considering the multiple benefits of CoPs in professional development, a CoP was established among the participants prior to the start of the 6-week professional development program. The domain of interest was decided to be “technology integration in engineering courses” after seeking consensus from all the participants. All the participants accepted to follow a few shared norms that required them to support each other in the process of developing TPACK. They mutually agreed to actively engage and collaboratively work on activities that were organized during professional development sessions. Participants were also expected to assist each other as they worked towards completing their final design project. The CoP members decided on the 6-week professional development program to be the first practice to that would help them evolve in the domain of interest. A consensus on other additional practices of the CoP was expected to be made after the end of the 6-week program.

2.8 Summary

The literature presented in this section provided a detailed account of the TPACK framework and highlighted the different studies that examined the process of development of TPACK. Most of the studies on TPACK were focussed in the K-12 setting, which resulted in the lack of proper understanding of how TPACK can be utilized in the higher education context. The TPACK framework has been widely used for in-service and pre-service teacher training to help teacher learn to integrate technology into their instruction. There is a lack of practical literature available for faculty developers who want to design professional development programs focussing on technology integration in higher education. A few researchers who examined the development of TPACK development conducted their studies as part of semester long courses. This study therefore looks at the experiences of faculty as they adopt a technology-enhanced instruction during a 6-week professional program. The findings from this study will contribute to our understanding of how TPACK could be used in a professional development context and highlight the strategies followed by the faculty to technologically enhance their course instruction.

CHAPTER 3. RESEARCH METHOD

3.1 Introduction

In this chapter, I describe the methods used to conduct the research. I present the detailed schedule of the 6-week professional development program and provide the reasoning behind the selection of methodology and sampling. The data collection process, information of the participants in the study, process followed to analyze the data, steps taken to ensure the validity and reliability of the study, and a positionality statement will be discussed.

3.2 Research Questions

The purpose of this research study was to understand the experiences of engineering faculty in India as they learn to integrate technology tools into their courses. The experience of interest include how they developed the various constructs of TPACK, how they used the different constructs to re-design a course, and what were some of the challenges they encountered during the 6-week program. At the end of facilitating and taking observations during the 6-week program, conducting semi-structured interviews, and collecting participants' reflections during and at the end the program, I investigated the following research questions. Note that these questions seek to understand different facets of the faculty's experience during the extensive 6-week program starting from the process of how they developed TPACK to revealing the major sources of support they utilized to complete the final design project.

1. How do faculty describe the development and using the various constructs of TPACK during the professional development experience?
    a. What is the process that the faculty followed while developing TPACK?
    b. How did the faculty apply the knowledge of TPACK to re-design a course?
    c. How did the development of TPACK influence the faculty's philosophy as an instructor?
2. What are the major challenges that the faculty encountered while integrating technology tools during the 6-week program?

d. What are some of the main sources of support the faculty used to navigate through them?
e. How did the faculty utilize their prior teaching and professional development experience to address some of the challenges?

3.3 6-Week Professional Development Program

To conduct the study, a 6-week professional development program was designed for engineering faculty by considering multiple best practice recommendations from prior literature that would result in the successful facilitation of professional development programs and technology-enhanced instruction. To ensure effective integration of technology in courses, participants were needed to be provided with ample opportunities in the professional development program that were embedded in school and classroom practices (Matherson et al., 2014). Table 3 lists the multiple successful professional development recommendations that were taken into account while designing the overall structure of the program.

Table 3– Best practice professional development recommendations from prior literature

	Prior Literature	Design of the 6-week program
1	Provide participants with opportunities to build the required knowledge and skills (Loucks-Horsley et al., 2009)	The latter half of each day of the 6-week program involved the participants working individually or in groups to contextualize the knowledge gained to their respective courses.
2	Create a learning community to promote meaningful exchange of knowledge among participants (Carter, 2009)	Community of Practice was established prior to the start of the professional development program. Participants mutually agreed to focus on a specific domain of interest – integrating technology into their courses.
3	Include active learning techniques that will promote the constructive engagement of participants in the sessions. (Murthy, Iyer, & Warriem, 2015)	A wide range of active and collaborative pedagogies were incorporated during the 6-week program. Think-pair-share activities were conducted during the start of the first 3 weeks of the program to help participants reflect on content presented in the previous day.

Table 3 continued

4	Opportunities for participants to provide feedback to co-participants. (Loucks-Horsley et al., 2009)	Participants on multiple occasions were asked to present their work at the end of the day and take peer-feedback.
5	Organize long intensive programs as compared to short-term programs. (Matherson et al., 2014)	The professional development program was scheduled for a duration of 6-week with the participants meeting for full day sessions three times a week.
6	Include collective participation of participants who belong to the same institution. (Garet, Porter, Desimone, Birman, & Yoon, 2001)	All the participants belonged to the same institution that hosted the 6-week program.
7	Employ a “learning by design” approach to provide participants with opportunities make design choices that would be critical to the effective integration of technology. (Koehler et al., 2004, Mishra, 2006)	All the participants were asked to submit a final design project where they re-designed an existing course of choice by integrating appropriate technology tools.
8	Activities should be meaningfully integrated into daily classroom and institutional activities. (Garet et al., 2001)	Participants throughout the 6-week program were provided with opportunities to apply the learning from the sessions to their respective courses. Participants were encouraged to think about how the knowledge gained in the session would assist the students’ in their learning. The professional development program was adapted to the context of the host engineering institution in India by ensuring that the final project is relevant and in line with the needs of the instructors and students.

3.3.1 Detailed breakdown of the activities and sessions during the 6-week program

Table 4 – Overview of 6-week professional development program

Week	Focus
Week 1	Understanding the Course Content - Introduction to backward design process and curricular priorities - Identifying the difficult concepts and misconceptions in the course - Evaluation of individual differences of students based on their prior background
Week 2	Pedagogy and Content - 7 principles of Making Learning Whole - Introduction to ICAP framework - Identification of pedagogical activities or tools based on the content for the course
Week 3	Technology - Introduction to various technology tools available for educational purposes - Conceptualizing the final project
Week 4	Content and Technology - Identification of technology tools needed to represent specific content - Developing and identifying learning resources to represent specific content using technology
Week 5	Pedagogy and Technology - Identification of technology tools needed to effectively implement the identified pedagogical activities - Integration of technology tool for classroom managements, receive feedback, etc.
Week 6	Technology, Pedagogy, and Content - Linking the various components of the final project together Presentation of final projects

Week 1

In the week 1 of the professional development program, the participants focussed on better understanding how their course content should be structured and how students in their course would learn the course content. Prior to the start of the 6-week program, all the participants were asked to select a course they were teaching to apply the learning from the professional development sessions. On day 1, participants were introduced to the backward design process and asked to establish the curricular priorities for their course. The backward design process is a three stage planning sequence for designing courses. In the first stage, instructors need to identify the desired results that they expect students to achieve after the completion of the course. This stage requires the instructors to decide on the content for their courses. Instructors in the second stage determined how they planned to assess students' learning in the course and develop appropriate assessment tools. In the last stage, instructors would decide on the pedagogy by planning the necessary learning activities that would help students achieve the desired results that were identified in stage one. The backward design process was introduced to the participants to emphasize on the importance of alignment between content, assessment, and pedagogy.

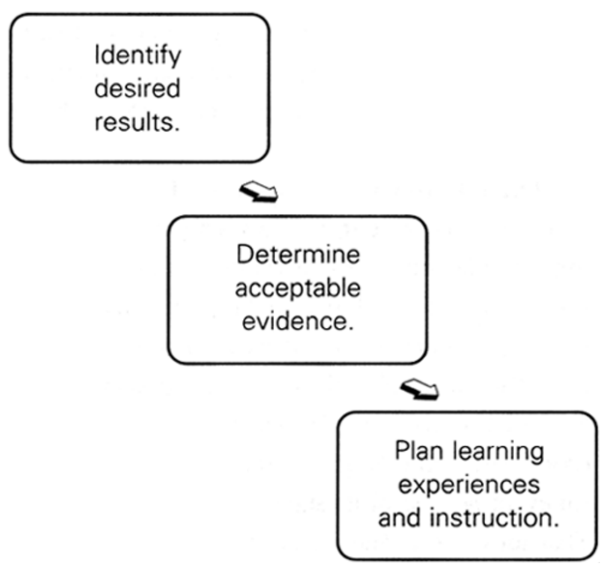

Figure 4 – Backward design process (Wiggins & McTighe, 2005)

The curricular priorities framework was later introduced to the participants to help them prioritize their course content. After introducing the framework, participants were asked to work individually to identify the enduring outcomes for their course and list the course content that would be categorized as "enduring" and "important to know"

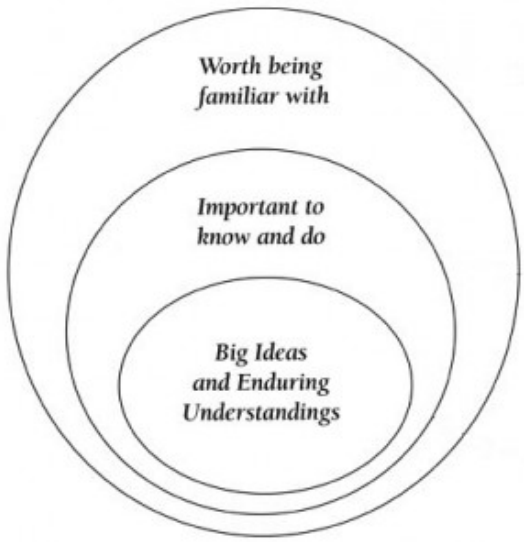

Figure 5 – Curricular priorities framework to prioritize course content (Wiggins & McTighe, 2005)

After working individually, participants engaged in think-pair-share activity where they shared the curricular priorities to their neighbour, and received and provided critical feedback (Kaddoura, 2013). To ensure meaningful interaction among participants, they were asked to pair with a neighbour from a similar discipline. Participants who belonged to different disciplines paired with individuals from closest associated discipline. For example, a participant from mechanical engineering was paired with another participant from civil engineering. At the end of the day, all the participants (after incorporating the feedback from think-pair-share activity) shared their curricular priorities with the whole group.

On day 2 of week 1, the focus of the sessions shifted to understanding how the students' learn the content in general and in the specific course they chose. Participants were introduced to the cognitive theory of learning that describes how new information is held in the working memory and how information from working memory is transferred to the long-term memory (Svinicki, 2004). An activity was conducted during the session to demonstrate how the principle worked in real-life. Participants were shown various methods to draw students' attention for the course content that was categorized as enduring understanding. Encoding strategies that could be used to transfer information from working memory to long term memory were also presented.

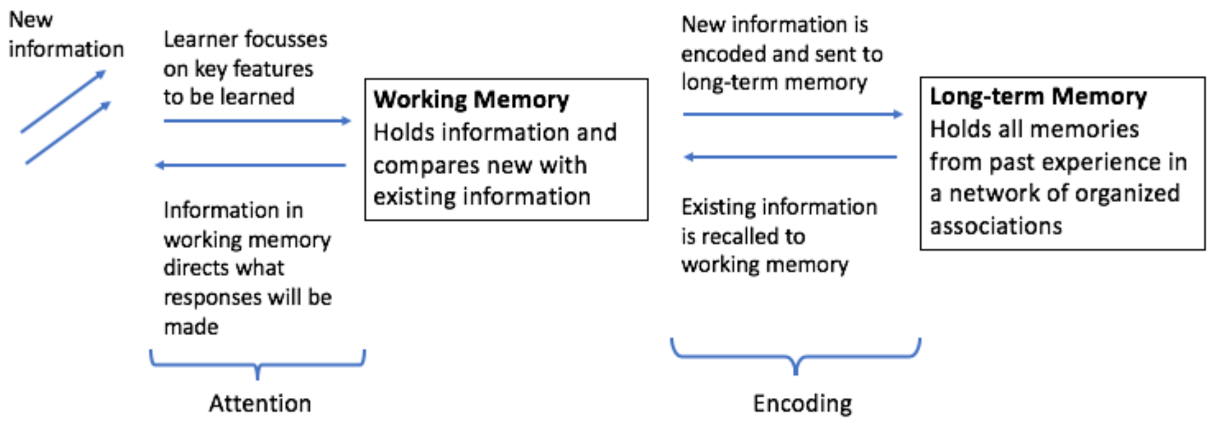

Figure 6 – Working descriptive of cognitive theory of learning (Svinicki, 2004)

Participants in the latter half of the day chose a topic they identified as an enduring outcome and applied the cognitive theory of learning. They identified strategies to capture students' attention and encode the content for that particular topic to the long-term memory. Similar to day 1, participants shared their strategies using a think-pair-share activity and later presented their work to the whole group.

On day 3, participants were introduced to why certain topics are considered as difficult concepts and how students develop misconceptions in the course. The education system in India often places most of the responsibility of learning the course content on the students with little help from the instructor. Participants were presented with the content on difficult concepts and misconceptions to make them understand the added responsibility that the instructors have to help students learn the course content. Participants in the latter half of the day spent time looking for literature on difficult concepts and misconceptions for their particular course. Some of the participants engaged in reflective practice to identify some of the misconceptions that students developed in their prior offering of the course.

Week 2

During the week 2, the professional development sessions focused on building the pedagogical knowledge of the participants. On day 1, participants were introduced to “Perkin’s 7 principles of making learning whole” which is a research-based framework that is used make learning in a course more effective (Perkins, 2010). As the name suggests, Perkin’s recommended 7 principles by using a baseball analogy and explained how a player must know different aspects of the game (hitting, catching, running) to be a good player. He correlated the baseball analogy to that of a course where students need to master the different components in the course to succeed.

Table 5 – Overview of Perkin’s 7 principles (Perkins, 2010)

Perkin’s principle of making learning whole	Description
Playing the whole game	Introduce the course by giving students a sense of the big picture. (i.e., how are the different topics aligned with the enduring outcomes of the course, what are the curricular priorities of the course)
Make the game worth playing	Increasing the motivation of students by creating a welcoming climate and inviting curiosity.
Work on the hard parts	Put additional emphasis on ensuring that the students learn the difficult concepts and overcome the misconceptions encountered in the course. Provide additional sessions in the course schedule to help students’ practice the hard parts. Include regular formative feedback to identify students’ misconceptions in the course.
Play out of town	Focus on transfer of learning to different context to develop higher order learning skills among students.
Uncover the hidden game	Include activities that will help students develop tacit knowledge.
Learning from the team	Provide opportunities to collaborate and work in teams. Include activities that will promote meaningful exchange of knowledge among students.
Learn the game of learning	Developing metacognitive skills among students by provide opportunities to reflect.

Instead of using the Baseball analogy, I explained the 7 principles using the game Cricket as Baseball is not widely played in India. I chose Cricket as it is one of the most widely followed sports in India and the structure of the game is similar to that of Baseball. After introducing Perkin's 7 principles, participants were asked to divide into two groups and work collaborative on an activity. In each group, every participant was asked to select two of the seven principles and apply them to their course. As a next step, each participant was asked to explain to the group the principle they selected and how it would be applicable to their course. As a last step, all the group members were asked to work collaboratively to develop a plan on how they would implement all of the 7 principles. The goal of the activity was to let each participant individually think how a particular principle would be applied to their course and then collaboratively develop ideas to implement each of the 7 principles. The activity was aimed to improve the participants' understanding of the 7 principles and correct any misconceptions that they might have developed in the process. In the latter half of the day, all the participants were asked to start analyzing how the Perkin's 7 principles would be applied to their respective courses.

On day 2, participants were presented with Chi's ICAP framework that links cognitive engagement to active learning outcomes (Chi & Wylie, 2014). The framework proposes that students' behavior in the classroom could be categorized into four modes: Interactive, Constructive, Active, and Passive. The framework suggests that students' engagement with the course content and learning increases as they move from passive to active to constructive to interactive. After introducing the framework, participants were asked to look for literature on different activities that would engage students in the active, constructive, and interactive modes. At the end of the day, participants shared their findings from the literature to the whole group. On day 3, participants were asked to work individually to apply their learning from days 1 and 2 and start designing pedagogical activities for their respective courses.

Week 3

In week 3, participants were presented with various technology tools that could be utilized for educational purposes. The technology tools were presented in different categories based on their intended use. An overview of all the technology tools is included in Appendix A. Participants were provided with a document containing the links to all the associated online tutorials that could be viewed to learn using technology tools. Participants were later asked to start conceptualizing their final design project and work on it in the consequent weeks. An activity on concept map was included to encourage the participants to combine their knowledge of content, pedagogy, and technology.

Week 3 – 6

During weeks 3 - 6, no formal presentations were scheduled. However, multiple activities were designed based on the three components of TPACK-in Practice, which were shown to promote effective transfer of TPACK to the participants' instructional practice. Table 6 provides details of the various activities conducted and their association with the three components of TPACK-in-Practice. During these weeks, participants were asked to continue progressing with their final design project. The activities mentioned in Table 6 were aimed to help participants in the completion of the final design project. At the end of each day, participants were asked to share their progress to facilitate meaningful exchange of ideas.

Table 6 – Components of TPACK-in-Practice during the 6-week Professional Development

Component of TPACK-in-Practice	Activity in Professional Development
Technological Pedagogical Content Knowledge (TPCK-in-Practice)	Participants identified technology tools needed to effectively carry out certain pedagogical content activities. The same tools were integrated in to the final project. (week 4-6)
Technological Content Knowledge (TCK-in-Practice)	Participants identified technology tools to represent course content and develop learning resources for the same (week 4).
Technological Pedagogical Knowledge (TPK-in-Practice)	Participants identified technology tools for various pedagogical activities such as classroom management, formative assessment, course feedback etc. (week 5). The identified tools will be integrated in to the final project (week 5-6).

3.4 Methodological Frameworks

I employed two methodological frameworks to design and analyze the data in this study. I used the framework of qualitative case study to design the study. I made my choices of data collection procedures, recruitment of participants, and facilitation of the 6-week professional development program using the lens of a qualitative case study to investigate the various ways in which the engineering faculty described experiencing the phenomenon of interest i.e., the development of TPACK. I later employed thematic analysis to analyze the data collected in the study. I used the thematic analysis approach to construct the prevalent themes about the process of development of TPACK and the challenges that the participants encountered in the process.

3.4.1 Qualitative case study

As the goal of the study was to understand the experiences of engineering faculty as they learnt to integrate technology into their courses during a 6-week professional development program, I employed a qualitative case study as the methodology for this study. A qualitative case study is used to study the particularity and complexity of a single case and understand its activity within an important circumstance (Stake, 1995). Stake defined a case as a specific and complex entity or system that has a boundary. The case in this study was the 6-week professional development program, as the goal was to examine the phenomenon of how the faculty developed TPACK as part of the program. The unit of analysis was the individual experiences of each of the participants during the entire six weeks of the program. A case study was well suited for this research, as I wanted to examine the experiences of a group of engineering faculty as they developed TPACK while integrating technology tools into their courses during the 6-week professional development program. The use of case study as a methodological framework will help us understand the complex phenomenon of the process of development of TPACK in a professional development context. More importantly, it would highlight in what ways the different activities and tasks carried out during the professional development program aided and hindered the process of development of TPACK.

The methodology used in this study can be further classified as a particularistic case study. In a particularistic approach, the case study is focussed on a particular situation, event, program or phenomenon (Shaw, 1978), and the case in itself is important for what it might reveal about the phenomenon. For example, the case in this study (the professional development program) was important as I wanted to examine how the participants developed TPACK by attending the professional development sessions, participating in different activities, and re-designing their course by completing the final design project in the limited 6-week time frame. The goal was to study how the TPACK framework could be applied and used in a faculty development context. Such case studies focus on the way a certain group of individuals confront specific problems or tasks by taking a holistic view of the situation. Particularistic case studies entail three characteristics that highlight the nature of study. The study should suggest to the reader some recommendations on what to do and what not to do in a similar situation, it could examine specific instances of the situation but should highlight the problem being addressed, and it may or may not be influenced by the author's bias (Merriam, 1998). After presenting the findings of this research, I use this case study to provide recommendations to faculty developers and higher education institutions on how to facilitate effective workshops or programs that are aimed to achieve the large scale adoption of technology-enhanced instruction.

Bromley reported that case studies by definition get as close to the phenomenon of interest (i.e., development of TPACK in this study) as possible by direct observations of the participants, and by having access to subjective factors such as beliefs, feelings, and thoughts (Bromley, 1986). Case studies are particularly suited for studies that are focussed on the process. The focus on the process could be viewed in two ways: 1. Monitoring: describing the context and participants in the study, discovering the extent to which a program was implemented, and providing immediate formative feedback, and 2. Causal explanation: discovering or confirming the process by which the program had an effect on participants (Merriam, 1998). One of the main goals of this study was to highlight the process of how the participants developed the various constructs of TPACK, and to develop an understanding of how the process varied among on the participants based on their prior teaching and professional development experience.

Qualitative case studies are also categorized as descriptive, evaluative, and interpretive based on the intent of the study (Merriam, 1998). In a descriptive study, a detailed account of the phenomenon under study is presented. The study is entirely descriptive and is useful to present basic information about areas of research where few studies have been conducted. Evaluative case studies, as the name suggests, are used for evaluating specific programs and involve description, explanation, and judgement. Interpretive case studies use thick descriptive data to develop illustrate, challenge, or support theoretical assumptions that were reported prior to the start of the study. The researcher in this case gathers a large amount of information with the goal to analyze, interpret, or theorize about the phenomenon. Interpretive case studies are also called analytical case studies due to the large amount of analysis involved in the process (Shaw, 1978). I took an interpretive approach to analyze the data, as the aim of this study was to also explain how the development of TPACK impacted the participants' teaching practice, influenced their teaching philosophy, and design choices while completing the final design project. The level of abstraction and conceptualization in this study will suggest the relationship between how participants developed TPACK, their prior teaching, and their professional development experience.

3.4.2 Thematic analysis

Thematic analysis was selected as a methodology to analyze the data collected in the study. Thematic analysis is often used as a method to identify, analyze, and report patterns within textual data (Braun & Clarke, 2006). In this approach, the researcher engages rigorously with the data to construct themes that represent the experiences of the participants in the study. The thematic analysis framework provided the structure to the data analysis process and the detailed step-by-step process is presented later in the data analysis section. Thematic analysis is often considered to provide many advantages for the analysis of qualitative data. It provides the researcher with the flexibility to make many choices during the data analysis process. For example, it allows the researcher to make a strategic decision of what counts as a theme in the data based on the research question being addressed in the study. The thematic analysis process also provides a well-documented approach to condense large amount of qualitative data into different codes and categories that provide a rich description of the phenomenon being studied (Guest, MacQueen, & Namey, 2011). I therefore used the thematic analysis process for the data analysis due to its simplicity, ease of use, and the availability of a well prescribed approach that could be used to generate the themes from the data collected.

3.5 Site of Study

The site of this study is KG Reddy College of Engineering and Technology (KGRCET), which is a small private undergraduate teaching-focused institution in the south of India. The institution was established in 2008 and is located in a rural setting with a goal to provide engineering education to students in the nearby regions. The majority of the students are first generation college students with their families' primary occupation being farming. The institution offers five undergraduate engineering programs: Computer Science and Engineering, Civil Engineering, Electrical and Electronics Engineering, Electronics and Communication Engineering, and Mechanical Engineering. The institution is regionally affiliated to the Jawaharlal Nehru Technological University Hyderabad (JNTUH), which is a regional government university responsible to regulate the quality of technical education in the affiliated institutions. JNTUH prescribes the syllabus to the regional engineering colleges and maintains the authority to conduct necessary assessments for students. KGRCET therefore has the autonomy to only innovate the pedagogy in the classrooms with no control over the content and assessment of the courses. The institution identifies itself in the tier-3 category of engineering colleges in India, and it is non-autonomous (no flexibility in deciding the curriculum and conducting student assessment) and is one of the many institutions in the state that are affiliated to JNTUH. There are more than 2000 similar tier-3 engineering colleges in India that are affiliated to their respective state regional universities (Krishna, 2014).

3.6 Sampling Framework

To develop the selection criteria for recruiting the participants in the study, I used a combination of purposive and stratified sampling that were identified by Patton for qualitative research (Patton, 2002). Purposeful sampling is used to identify a certain section of the population that would provide in-depth rich insight into the phenomenon of interest in the research study. The object or unit of analysis in this study was the experiences of engineering faculty as they integrated technology tools into their courses as part of a 6-week professional development program. Engineering faculty who attended the professional development program described their experience with the phenomenon of interest i.e., development of Technological Pedagogical Content Knowledge (TPACK). This study focused on engineering faculty who taught undergraduate engineering courses at KG Reddy College of Engineering and Technology (site of the study) as all the faculty who participated in the professional development program belonged to the same institution.

Another dimension that was combined with the sampling technique is stratified sampling. Stratified sampling technique is used to control for certain identifiable subpopulations within the larger sample population. In a stratified sample, the researcher selects a set of a categories or group of cases that they consider should be included in the final sample (Robinson, 2014). The sample is then stratified based on the identified categories to recruit the final group of participants. The participants in this study were stratified along three dimensions to achieve a maximum amount of variation in the participants' response. The three dimensions of stratification were the number of years of prior teaching experience, discipline of engineering, and prior knowledge of the various TPACK sub-domains and intersecting sub-domains i.e., content knowledge, pedagogical knowledge, technological knowledge, pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge. The stratification was informed by prior literature that reported the development of TPACK to vary based on the three identified dimensions. It was observed the effective integration of technology tools into courses was dependent on the prior experience of the instructors, as only the instructors with extensive teaching experience were able to develop TPACK (Niess, 2011). I therefore included the number of years of prior teaching experience as the first dimension of stratification. The second dimension was selected as the discipline of engineering as TPACK often varies based on the context of operation and the domain of the field (Charoula Angeli & Valanides, 2009). The third dimension was informed by the study conducted by Hosseini and Tee who reported the development of TPACK to have varied based on the instructors' knowledge of TPACK sub-domains and intersecting sub-domains (Hosseini & Tee, 2012).

3.7 Data Collection

Multiple sources of data were collected to examine the experiences of the participants during the 6-week professional development program. During the 6-week program, each of the faculty participants was individually interviewed at the end of every two weeks (week 2, 4, and 6) using a semi-structured interview protocol. One round of semi-structured interviews were also conducted with the participants prior to the start (week 0) of the 6-week program. The semi-structured interview protocol was designed to probe different facets of the participants' experience every two weeks. The interview questions asked the participants to describe their experience during the professional development sessions every two weeks, explain the influence of their prior teaching experience, and highlight some of key challenges they encountered. Some of the interview questions varied with the week of the professional development program depending on the activities and tasks taken up by the participants during the two weeks. The semi-structured interviews also probed the participants about the experience that stood out during the 6-week professional development program and asked them to emphasize on the key instances that influenced the development of their TPACK. During the instrument development phase, I conducted cognitive interviews with other engineering faculty from the same institution to test the language of the semi-structured interview protocol. Cognitive interviews assess the respondents' understanding of the questionnaire and are used to improve instrument design (Knafl et al., 2007). To conduct the cognitive interviews, I individually met with two different faculty and asked them to interpret their understanding of the questionnaire. Based on the results of the cognitive interviews, I included additional clarification for specific questions in the interview protocol where the faculty had difficulty in understanding. The semi-structured interview protocols for each week are provided in Appendices B, C, D, and E. In total, 28 semi-structured interviews were conducted throughout the 6-week program with the average duration of the each interview being approximately 20 minutes. All of the semi-structured interviews were audio recorded and later manually transcribed into a separate word document.

Another source of data was collected in the form of field notes during the 6-week professional development program. During the 6-week program, I kept switching between my role as the facilitator and the researcher of the study. When I was not presenting any content to the participants, I kept taking notes of different instances that I believe would be useful to understand the process of development of TPACK. I took field notes throughout the 6-week professional development sessions as the participants interacted with each other, shared their queries, worked on various activities, and completed their final design project. I made a note of observations that I believed would be important and useful to answer the research questions being addressed in the study. Participants were also asked to maintain a reflection journal throughout the 6-weeks of the professional development. The participants were provided with prompts to reflect at the end of each day of the professional development and asked to answer the questions in their reflection journal. The questions provided as part of the reflection prompts are included in appendix H.

During the 6-week program, the participants developed multiple iterations of concept maps while constructing knowledge of the intersecting TPACK sub-domains (pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge) and while generating ideas for the final design project. The different versions of the concept maps were also collected and stored as an additional source of data. After the end of the 6-week professional development program, each of the participants were asked to submit a final reflection paper which elaborated in detail the participant's experience throughout the professional development program, how the experience helped them to integrate different technology tools into a course of their choice, their thoughts on developing the final design project, and other issues related to the development of TPACK. Participants were also asked to elaborate on how their teaching philosophy changed at the end of the 6-week program after the development of TPACK. Participants were provided with guiding questions which were aimed to help them write the final reflection statement. The guiding questions are listed in Appendix F.

A design-based research approach was used during the data collection process to make changes or additions to the data collection instruments. In a design-based research approach, the participants are treated not just as subjects, but instead are treated as co-participants during the design of the study (Barab & Squire, 2004). Design-based research is often employed for studies that focus on examining human interactions with the phenomenon of interest (Reeves, Herrington, & Oliver, 2005). The semi-structured interview protocols were initially developed to gain an understanding of the different facets of the participants experience during the 6-week program. The questions asked the participants to describe what they did the during the professional development sessions, the challenges they encountered every two weeks, and how they navigated through those challenges. The experience of the participants was expected to change depending on the week of the professional development and three different interview protocols were developed for weeks 2, 4, and 6 respectively. In a design-based approach, participants are treated as co-researchers while developing the research instruments. Based on the interview responses of the participants, I kept revisiting the instruments used in the study to make changes and include additional questions that might be helpful to address the research questions. For example, many of the participants during the weeks 2 and 4 interviews mentioned to receive support from the CoP members. The interview protocol however did not include any questions that enquired the participants on how the formation of CoP influenced their professional development experience. I therefore included an additional question in the week 6 interview protocol that said *"How did establishing a CoP at the start impact your experience in the last 6 weeks?."* The design-based approach, as a result, helped me gather data that elucidated certain aspects of the participants experiences that would not be possible to analyze using the instruments developed prior to the start of the 6-week program. Figure 7 provides a detailed timeline of the instrument development, data collection, and data analysis process.

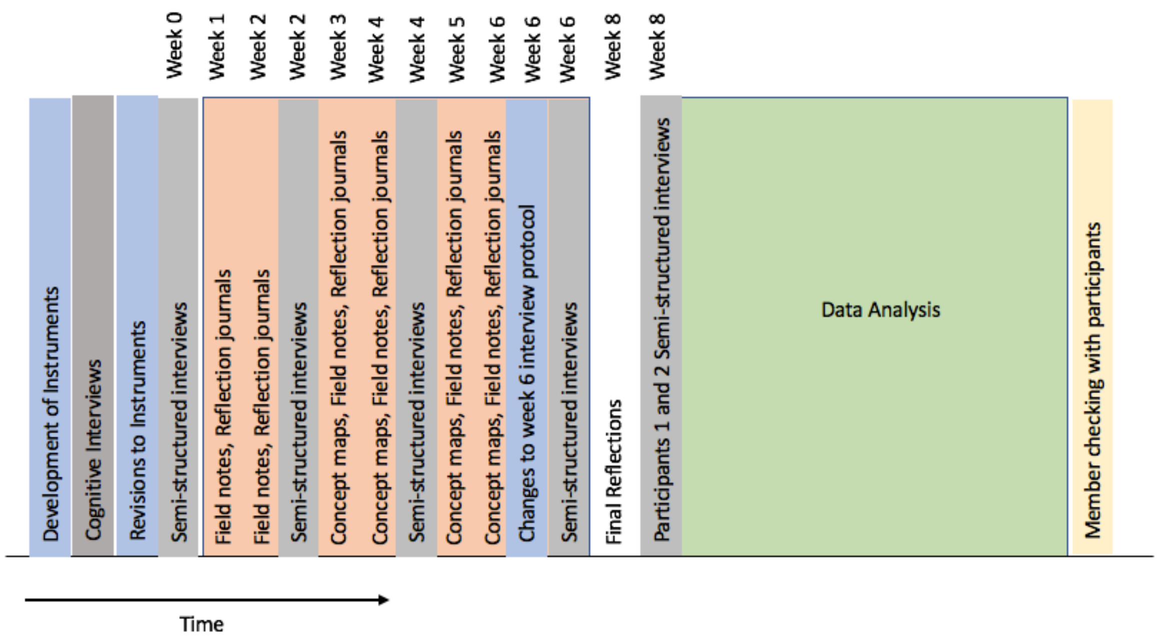

Figure 7 – Timeline of data collection and data analysis process

3.8 Participants

The recruitment process of the participants for the study was done internally by the principal, who is the head of the institution. The three categories of stratification i.e., discipline of engineering, prior teaching experience, and prior knowledge of the TPACK constructs were sent to the principal as necessary guidelines for the recruitment process. The principal then sent out a call to all the faculty in the institution about the 6-week professional development program. Faculty who were interested to integrate technology tools into their courses were asked to notify him about their intention to participate in the program. The principal, after receiving a list of interested faculty, selected the final list of participants to meet the stratification criteria.

In total, seven faculty with varied prior teaching experiences were part of the 6-week professional development. All of the participants were faculty at KG Reddy College of Engineering and Technology, who were teaching sophomore, junior, and senior level engineering courses. Each of the participants selected a course they were teaching in the Fall of 2018 to re-design it using technology tools during the professional development. Detailed information about each of the faculty is presented below by providing appropriate quotes from their week 0 interview. The prior knowledge of the participants was categorized by looking at their responses in the week 0 interviews and mapping their self-reported prior teaching experiences to the different dimensions the TPACK framework as defined by Mishra and Koehler (2006)

3.8.1 Participant 1

Participant 1 in the study was newly recruited into the Department of Civil Engineering at the institution. She completed her bachelor's in Civil Engineering and master's in Structural Engineering. Participant 1 had no prior teaching experience and was teaching the course for the first time. Her previous experience with the course was during her under graduation as a student (3 years ago), and she reported to have been revisiting the course content while preparing to teach the course. She mentioned to be teaching a subject that is not her area of specialization:

> *"I am teaching a subject that is not my area of specialization… so preparing for the course is challenging as I'm trying to learn it again myself."*

Her content knowledge about the course was therefore intermediate. When asked about her knowledge about pedagogy prior to the start of the professional development, the participant responded,

> *"What do you mean by pedagogy? I haven't used any until now."*

As part of their preparation to teach a course, all the faculty in the institution were expected to develop lesson plans and a course file that is given to the students to provide them with necessary resources (course outline, schedule of semester, references, and textbooks). Participant 1, due to lack of prior professional development experiences, had low pedagogical knowledge. During the interview, the participant also mentioned to be struggling with classroom management as was trying regulate the pace of lectures:

> *"First 2 weeks, students mentioned that I teach very quickly and they are unable to understand. Now I'm trying to check with students if they are able to understand in the class."*

She had low technological knowledge as she mentioned to have never used any technology tools for teaching but had a general understanding of using Microsoft office tools such as Word, Excel, and PowerPoint. Participant 1 had no pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge as this was her first time teaching the course.

3.8.2 Participant 2

Participant 2 was from the Department of Electronics and Communication Engineering and had two years of prior teaching experience. She had a bachelor's in Electronics and Communication Engineering, master's in Embedded Systems, and was teaching a course that was newly recommended by the affiliated university. While the course was new, she reported to have prepared well for it prior to the start of the semester. She mentioned the course to be focussed on developing conceptual understanding of the students with little emphasis on its practical applications in real life. As it was her first time teaching and learning the course, participant 2 as a result had intermediate content knowledge. She had attended professional development workshops on student-centered learning and implemented active learning in the classroom. Participant 2 had intermediate pedagogical knowledge as she used a range of student-centric activities:

> *"activities such as interactive sessions, think-pair-share, and collaborative learning practices"*.

She also mentioned the rationale behind using such techniques based on individual differences of the students in her course:

> *"For 2^{nd} years (sophomore-level students), I implemented collaborative learning strategies because sometimes students might feel shy and not clarify their questions in the class. I group students based on who are fast and slow learners, so that if students have any questions, they can ask their peers."*

However, participant 2 had no pedagogical content knowledge, technological content knowledge, or technological pedagogical knowledge as this was her first time teaching the new course.

3.8.3 Participant 3

Participant 3 had six years of teaching experience and taught courses in the Department of Mechanical Engineering. She completed her bachelor's in Mechanical Engineering and master's in Thermal Engineering. She mentioned that she was teaching a course "Engineering Drawing" that is perceived to be difficult by freshmen engineering students. She had taught the course multiple times and as a result possessed high content knowledge. She has attended multiple professional development programs that were focused on the need to interact with students, strategies to get students' attention, and student-centered learning. She had high pedagogical knowledge as she reported to use active learning strategies:

> *"My classes continue for 3 hours. If I conduct activities in the class, such as think-pair-share, students will be active in the classroom."*

In her interview, she mentioned the need for additional effort to help freshmen students transition to the engineering program:

> *"I teach Freshmen students and I need to provide extra emphasis to them to help them get accustomed to the engineering program."*

She possessed intermediate technological knowledge as she used the standard set of software tools for preparing lesson plans and course files for students, and developed PowerPoint presentations for her course. Participant 3 used collaborative learning practices based on her understanding of the learners in the class:

> *"After completing one topic, I get to know which students are having trouble understanding the course content and which students are understanding the content. I ask these two set of students to pair up and work on a few problems so that they can help each other".*

However, she did not mention to use any pedagogical techniques that were specific to the content of the course and were targeted to help students achieve the course objectives. She also did not have the knowledge of the concepts that were perceived to be difficult by the students and therefore had low pedagogical content knowledge. She had low technological content knowledge as she used online videos to help students' understand certain concepts in the course:

> *"I have used NPTEL videos... I used the videos because in Engineering Graphics, it [solving problems] is a step-by-step process. If I show them the process using animation, students will understand the content better".*

3.8.4 Participant 4

Participant 4 taught computer science and engineering courses for freshmen and sophomore level students and had ten years of prior teaching experience. He completed his bachelors and masters in computer science and engineering and was teaching a course, Database and Management Systems, which belonged to his area of specialization. He had taught the course during multiple semesters and possessed high content knowledge. He recently attended one professional development program on active learning strategies for 21st century learners and used pedagogical approaches such as think pair share, case-studies, and collaborative learning (intermediate pedagogical knowledge).

> *"to deliver my course effectively, I conducted some group activities like case studies, collaborative learning process, think pair share, and quizzes."*

Being a faculty from the Department of Computer Science and Engineering, he had the knowledge and skills of using computer-based technologies (high technological knowledge). He mentioned in his interview that he had a basic understanding of representing certain concepts using PowerPoint presentations and online videos and as a result had intermediate technological content knowledge:

> *"I don't have much knowledge on educational tools and its implementation. But I am using ppts to present the diagrams and I am using online NPTEL videos,"*

However, he was not aware of the difficult concepts in the course and had not adapted his pedagogical techniques based on the course content or the needs of the learners (low pedagogical content knowledge).

3.8.5 Participant 5

Participant 5 had nine years of prior teaching experience and taught junior and senior level courses in the department of Electronics and Communication Engineering. She completed her bachelor's in electronics and communication engineering, master's in VLSI System Design, and is currently pursuing her Ph.D. in Antenna Design. Her research interests were aligned with the course she was teaching (and selected for the professional development) and she possessed high content knowledge. She attended multiple professional development workshops that included topics such as outcome-based education and student-centered learning. She implemented active learning activities to get students' attention in the classroom:

> "*I implemented active learning activities, such as minute-paper, taking quizzes, thumbs up and thumbs down. I implement these to make students active because whatever we teach, after 15-20 minutes, if the session is not interesting, students might not be able to be attentive while learning."*

She reported to not have any challenges in terms of classroom management and stayed attentive of students' learning in the class:

> *"one day if I couldn't get the attention of the students, next class I will take a different approach while teaching. I reflect on it and make changes."* Participant 5 therefore possessed high pedagogical knowledge.

She had used software tools to create lesson plans (intermediate technological knowledge), and used externally developed animated videos to represent specific content for the course (low technological content knowledge):

> *"I show students some animated videos for certain concepts which can be better explained by using animations. Such as internal operation of magnetron, how an electromagnetic wave travels, etc."*

Although participant 5 had extensive prior teaching experience and might have an understanding of how students learn the course, she did not report to make any changes that specifically supported students' learning in the course (low pedagogical content knowledge).

3.8.6 Participant 6

Participant 6 completed his bachelor's in Electrical Engineering, masters' in Power System, and was completing his Ph.D. in Sensor Less Control of Inductive Motor Drives. He had ten years of prior teaching experience and was teaching a course that was his area of expertise and he has taught the course multiple times (high content knowledge). Participant 6 has attended different professional development workshops and certification programs on teaching and learning. He reported the certification program to be a combination of different modules:

> *"One of the course is engineering education certification program where they introduced 6 of the modules. The modules included curriculum planning and development, dynamic classrooms, harnessing power of technology i.e., introducing ICT into classroom, collaborating learning methods, and active learning methods."*

He pedagogically innovated his lectures by implementing learning from his prior professional development and had high pedagogical knowledge. He reported to have an understanding of ICT tools (intermediate technological knowledge) and how they could be used to implement different pedagogical techniques in the classroom (intermediate technological pedagogical knowledge):

> *"through ICT tools, we could use flipped classroom and have more active discussion in the classroom."*

He also possessed intermediate pedagogical content and technological content knowledge, as he had an understanding on why certain topics are difficult for students to learn, and used pre-developed animated videos to help students understand the operation of those topics:

> *"There are a few internal operations of an electrical machine where I have to explain the operation manually and sometimes the imagination of the students will not be to an extent where they could visualize the whole process… I have used animated videos sometimes."*

3.8.7 Participant 7

Participant 7 had the highest years of teaching experience (15 years) among all the participants and taught courses in the department of Computer Science and Engineering. He taught the course multiple times in the last five years (since the course was designed and prescribed by the affiliated university) and possessed high content knowledge. Participant 7 had attended many professional development workshops that included topics such as Outcome-based education, Service Learning, and Active Learning for STEM courses. He implemented collaborative learning, flipped classroom, and project-based assignments as part of his teaching practices (high pedagogical knowledge). He implemented project-based assignments to help students achieve higher-level cognitive learning outcomes in the course and had high pedagogical content knowledge:

> *"I asked students to use C program to solve mathematical and engineering Mechanics problems to build their logical reasoning skills,".*

Participant 7 possessed high technological knowledge as he had extensive knowledge of operating systems, computer hardware, and software tools. He used technology tools in the classroom before and as a result had intermediate technological pedagogical knowledge:

> *"I used Google classroom tool to share the course content and assess the students learning through quiz,"*.

He also used professionally developed videos available online to demonstrate certain algorithms to the students in his course (intermediate technological content knowledge). Table 7 and Table 8 provide a detailed summary of the participants based on their area of specialization, prior teaching experience, prior professional development, and prior knowledge of the various constructs of TPACK.

Table 7 – Overview of the participants based on discipline, prior teaching experience and professional development

Name	**Discipline**	**Prior Teaching Experience**	**Prior Professional Development**
Participant 1	Civil Engineering	None	None
Participant 2	Electronics and Communication Engineering	2 years	Low
Participant 3	Mechanical Engineering	6 years	Intermediate
Participant 4	Computer Science and Engineering	10 years	Low
Participant 5	Electronics and Communication Engineering	9 years	Intermediate
Participant 6	Electrical Engineering	10 years	High
Participant 7	Computer Science and Engineering	15 years	High

Table 8 – Overview of the participants based on prior knowledge

Name	CK	PK	TK	PCK	TCK	TPK
Participant 1	Intermediate	Low	Low	None	None	None
Participant 2	Intermediate	Intermedi-ate	Intermediate	None	None	None
Participant 3	High	High	Intermediate	Low	Low	None
Participant 4	High	Intermedi-ate	High	Low	Low	None
Participant 5	High	High	Intermediate	Low	Low	None
Participant 6	High	High	Intermediate	Intermediate	Intermediate	Intermediate
Participant 7	High	High	High	High	Intermediate	Intermediate

As observed, the prior knowledge of content, pedagogy, and technology varies with each of the participants and this variation will provide the study with rich qualitative data that will help address the research questions in the study.

3.9 Data Analysis

A thematic analysis approach was employed to analyze the data and the six-phase approach as suggested by Braun and Clarke was used to thematically analyze the data (Braun & Clarke, 2006).

1. Familiarize yourself with the data
2. Generate initial codes
3. Search for themes
4. Review themes
5. Define and name themes
6. Produce final report

In the first phase, I read through each of the transcripts twice to become familiar with the data and this process allowed me to have a holistic sense of the participants' experiences during the 6-week program. By familiarizing myself with the data, I was also able to develop an understanding of how the individual experiences of the participants progressed through the different stages of the data collection process.

The next phase involved coding the data to generate the initial of codes. I chose an inductive approach to code the data where the coding is more data-driven and the codes help to organize the data into meaningful groups. In the inductive approach, I identified quotes of text that are significant to the study and provided codes to each of the quotes. I gave each code a definition to describe when the code should be applied to the text. After generating the list of codes, I constructed categories that would consolidate similar codes into a related understanding that provided meaning to the codes (Guest et al., 2011). The coding was an iterative process as many codes would often be merged into a single code and some codes would be refined to make better sense of the data. The coding was done using the NVivo software where the data was tagged to appropriate codes to create coded data extracts. The data were coded in such a way that the coded extracts retained the surrounding information when necessary. The inductive coding of the data resulted in a list of 49 codes that were finally reduced through to a final count of 26 codes. The 26 codes were initially grouped into 10 categories which were eventually reduced to 7 categories after continuous refinement. There was one orphan code that did not fit into any of the categories. The list of the codes and categories along with their definitions are included in Appendix I.

The third and fourth phase of the thematic analysis involved searching and refining of themes. This process involved considering the different codes and categories in relation to the research question and determining how the data could be combined to form a theme. A theme should capture something important about the data with respect to the research question, and represents some level of meaning or patterned responses within the data set (Braun & Clarke, 2006). The reduction of themes from codes and categories was done through the researcher's interpretivism as I constructed larger meaning from experiences of the participants during the 6-week professional development program (Guest et al., 2011). Some of the themes were divided into sub-themes to give them a structure and indicate a hierarchy of meaning within the main theme. The thematic analysis process resulted in the generation of four themes with two of the themes having additional sub-themes. The generation of themes was an iterative process that was carried out to ensure each theme told a coherent story of the participants experience as they learnt to integrate technology tools into their courses. I developed thematic maps for each of the themes to show how they were constructed in relation to the codes and categories. The thematic maps are included in the next chapter. A theme was constructed when the majority of the participants reported similar instances during the 6-week program or when a particular experience captured something important in relation to the research questions. The last two phases involved defining and naming the themes and generating the final report of the analysis. The goal was to define the theme in such a way that it demonstrates what aspect of the data it captures. The results presented in the next chapter completes the final phase of the analysis.

3.10 Positionality Statement

In this section, I discuss my positionality as a faculty developer, researcher of this study, and my relationship with the participants and the institution. I believe my interest in faculty development started while I was associated with KG Reddy College of Engineering and Technology (KGRCET) as a founding member of their Center for Engineering Education Development (CEED). My experiences as an undergraduate engineering student in India further motivated me as I started to realize that the lack of faculty training has become a major challenge in the engineering education system. In 2015, I started to work with the other members of CEED to develop short workshops that introduced the faculty to different active learning methodologies. The workshops were aimed to gradually change the institutional culture from a passive teaching format to engaging students actively in the classroom.

In 2016, I transitioned to my current role as an engineering education PhD student at Purdue University and started working with the Freeform research group. Freeform is an Active, Blended, and Collaborative (ABC) learning environment that was implemented in a core mechanical engineering course at Purdue. I was working to qualitatively understand students' experiences in the course and analyze how they engaged with the various learning resources provided as part of the learning environment. The results from my research work shed light on the benefits of designing innovative pedagogical frameworks by integrating technology in courses. At the same time, I was also part of teams that conducted faculty development workshops for universities in Ethiopia and Colombia. The workshops helped me to continue developing my skills as a faculty developer and have a better understanding of how the programs should be tailored depending on the local contexts of the institution. While I started to intersect my identity as a faculty developer and as an engineering education researcher, I came across the TPACK framework that could be used for effective and true integration of technology into courses. I conducted an extensive literature review of TPACK as part of my readiness assessment (equivalent to the PhD qualifier) and found that the framework is widely used in the K-12 for teacher training and has not been implemented in the higher education settings. This inspired me to use the TPACK framework to design a professional development program which could be used as a case-study to understand how engineering faculty learn to integrate technology into their courses.

The Content, Assessment, and Pedagogy (CAP) course I took as part of my PhD requirements at Purdue guided me while designing the professional development program. I also served as an apprentice faculty in the CAP course to develop my skills as a facilitator and instructor. I used the "Understanding by Design" approach (Wiggins & McTighe, 2005) introduced to me in CAP to build the foundation of the professional development program. I combined the knowledge I gained in CAP with the TPACK framework to design an extensive 6-week program for engineering faculty in India. I choose KGRCET in India as the site of my study due to two main reasons. My connections with the institution made it convenient for me to get the necessary buy-in from the administration to conduct a 6-week long program. The faculty in the institution were expected to teach two courses every semester and carry out other research or administrative tasks. As the 6-week program required the faculty attend 3 full day sessions every week, it was important for the administration to reduce work load and allow the faculty to teach only one course. The second reason for the site of the study is the growing need for faculty development in India. The AICTE has recently announced to make faculty development mandatory for all engineering faculty in India. I believe the findings from my study would inform faculty developers on how to design programs that are focussed on helping faculty utilize technology in courses.

As a researcher in this study, I believe it is important to acknowledge the power differential that might have been present as part of my relationship with the participants. With few of the institutional board members being members of my family, it was important for me establish certain protocols before the start of the 6-week program. During my previous role in the institution, I had the opportunity to work with two of the seven participants in this study. Both of the faculty were members of CEED and helped me to facilitate the workshops in the institution. However, it was my first time working with the other five participants. During the week 0 interviews and on the first day of the professional development program, I made it explicit to the participants that my relationship with them would be limited to a researcher and faculty developer. The participants were informed that my observations during the 6-week program and the data collected would not be shared with anyone in the institution and will not be used as part of their annual review. I scheduled a few interactions with the participants before the start of the program to establish a relationship with them as a facilitator and resolve any concerns they might have had as a result of the power differential. This was important to try and avoid any potential bias in the participants responses during the data collection process. During the 6-week program, I often switched hats between a facilitator and researcher when I had to take field notes of observations that might be of interest to the study. My observations as a researcher also informed me to incorporate a few additional activities that were initially not planned as part of the during the 6-week program. The additional activities were incorporated to help the participants successfully integrate technology tools into their courses.

3.11 Validity and Reliability of the Study

Validity and reliability are often associated with rigorous research studies. Validity has been used to determine if the research study has rightly measured what it intended to measure. Reliability is referred to the consistency when repeating or comparing assessments within a study (Guest et al., 2011). Qualitative researchers believe that the reliability of qualitative studies is often dependent on the researcher's paradigm and therefore provided different terminologies and methods to conduct reliability checks (Golafshani, 2003). In this study, I use Tracy's eight "Big-Tent" criteria for excellent qualitative research to showcase the rigor and the quality of the study (Tracy, 2010).

Eight criteria for excellent qualitative research

1. Worthy topic
2. Rich rigor
3. Sincerity
4. Credibility
5. Resonance

6. Significant contribution
7. Ethical
8. Meaningful coherence

3.11.1 Worthy topic

Tracy qualified a study to be a worthy topic when the qualitative research is relevant, timely, significant, and interesting. The phenomenon of interest in this study i.e., the development of TPACK is a widely research topic in the last two decades. In the chapter 2, I provided detailed insights into prior work that described the development of TPACK including a chronological account of the evolvement of the framework. In spite of TPACK being a widely researched topic, most of the work that was published focussed on situating the framework in the K-12 setting for in-service and pre-service teachers. In this study, I apply the framework to a professional development setting that is situated in the higher education context. The motivation for the study was the lack of widespread adoption or integration of technology tools in higher education settings in spite of the many known benefits to the students learning process. The findings from this study will provide faculty developers with best practice recommendations that could be used to design effective faculty development programs and help the faculty to integrate technology tools into their courses.

3.11.2 Rich rigor

Rigor is often used as a convenient representation of validity in qualitative research (Golafshani, 2003). One parameter of judging the rigor of a study is reflected in the care taken by the researcher to collect and analyze the data. In the previous section, I provided a detailed account of the instrument development process, different stages of data collection, and steps taken to analyze the data. I started by giving a rationale of my choices for selecting qualitative case study and thematic analysis as the two research methodologies for the study. I later provided the reasoning behind my sampling choices by grounding my stratification in prior literature. A detailed account of the instrument development process was given along with the type of questions that were asked. I included the semi-structured interview protocols and reflection prompts that were used throughout the 6-week professional development program in the appendix. I also discussed the data collection procedure to highlight how different sources of data were collected during the 6-week program and how I used a design-based research approach to modify some of the instruments in the process. In the last section, I elaborated on the step-by-step process that I carried out during the thematic analysis and provided details of the codes and categories that were developed during the process. I included the codebook in the appendix by providing appropriate definitions for each code. In the next chapter, I provided the thematic maps that were used to develop the themes to showcase to the reader the process by which I organized raw data into different themes and sub-themes. All of these steps were highlighted to provide transparency to the data collection and analysis process.

3.11.3 Sincerity

Sincerity is defined as the researcher's honesty and transparency about the their biases and goals, and how these elements played a role during the research study. One of the steps I took to achieve sincerity in the study is by ensuring to be transparent throughout the research process. Transparency is achieved by providing a clear documentation of all the research decisions and activities that were conducted as part of the study (Creswell & Miller, 2000). I provide a clear detailed account of all the professional development sessions and activities, how the different sources of data were collected, the steps taken to analyze the data, detailed description of the final list of codes and categories, and how the themes emerged from the different codes and categories. Apart from maintaining a clear documentation of all the research decisions and activities, I included a positionality statement in the previous section to acknowledge my bias in focussing on the engineering education context in India, the selection of the research topic, selection of the site of study, prior relation with some of the participants, and the shifting of my identity between a researcher and facilitator during the 6-week professional development program.

3.11.4 Credibility

Credibility refers to the plausibility and trustworthiness of the research findings. I used thick description, triangulation, and member reflections as three approaches to ensure the credibility of the findings. Thick description means providing in-depth illustration that include abundant concrete detail about the surrounding and the context. To illustrate the complexity of the data, researchers are advised to provide enough detail to the readers to ensure they come to their own conclusion about the situation. In chapter 4, I detail the themes that emerged from the data by providing quotes from the participants' interviews and reflections. I presented each quote by providing the reader with enough details about the context which would help them to come to their own conclusion about the participants' experience during the 6-week professional development program. I describe the participants' experience in their own words as I provide the necessary context as the researcher. Relevant quotes are included for all of the themes and sub-themes illustrated in chapter 4.

The second approach I used to ensure the credibility of the data is triangulation. The conclusion of qualitative research is considered more credible when the two or more data sources, theoretical framework, or researchers converge on the same conclusion. I used multiple approaches to triangulate the findings in the study. As a first step, I conducted intercoder reliability checks on my codebook with a colleague who agreed to assist me in the data analysis process. After developing the first list of inductive codes and code definitions, I conducted two rounds of intercoder reliability checks. In the first round, I provided my colleague with 3 interview transcripts (one each from week 2, 4, and 6) and asked him to code the interviews. Analysis of the coding of the three transcripts resulted in a 73% agreement between us about the codes. We then engaged in thoughtful discussions to rename a few codes to better define what the code is expected to capture in the data. In the second round, the same process was carried out on three different interview transcripts using the modified codebook, which resulted in 84% agreement between us about the codes. As another strategy for triangulation, I used the multiple data sources collected in this study to triangulate the findings. I cross-verified the results with the semi-structured interview data, field notes, entries in the participants research journal, and the final reflection submitted by the participants. As the last strategy, I triangulated the findings of the study by grounding the discussion using prior literature when necessary.

I used member reflections as the third approach to ensure the credibility of the research. Member reflections is a strategy that involves the researcher to seek input from the participants during the analysis of the data and producing the report. After recording and transcribing the data, I conducted member checking with all the participants and asked them to report any discrepancies in the transcribed data. After the completion of the data analysis process, I presented the themes and sub-themes to all the participants to ensure that the findings provide a true interpretation of their experiences during the 6-week professional development program.

3.11.5 Resonance

Resonance is referred to the researcher's ability to meaningfully reverberate and affect an audience and can be achieved by providing details of the transferability of the findings. By discussing transferability, a researcher demonstrate the study's potential to be valuable across a variety of contexts or situations. I discussed the transferability of the study as talked about the different higher education contexts in which the findings can be transferable in the limitations section.

3.11.6 Significant Contribution

I highlight the significant contribution of the study by presenting the implications of the findings in chapter 5. I provided valuable insights for faculty developers and higher education universities in relation with the findings of the study. I include best practice recommendations for faculty developers and higher education administrators to showcase the practically significance of the study. The recommendations for faculty developers were aimed to help them design effective professional development program that would help faculty integrate technology tools into their courses. I provided suggestions for administrators at higher education universities who wish to support their faculty and revamp their undergraduate courses through large scale adoption of technology-enhanced instruction.

3.11.7 Ethical

Ethics refers to the ethical actions that are universally necessary as dictated by large organizations, institutions, or governing bodies. I applied and received the approval for an exempted study from the Institutional Review Board (IRB) at Purdue University. The IRB upon the submission of the application asked me to provide a letter from the representatives at the site of the study allowing me to organize the 6-week professional development program and conduct the research study. The IRB approval and letter from host institution are included in the Appendix I and J respectively.

3.11.8 Meaningful Coherence

Meaningful coherence is achieved by eloquently interconnecting the research design, data collection, and analysis with their theoretical framework and situational goals. The goal of this research study was to understand how engineering faculty learnt to integrate technology tools into their course in a professional development setting. I used the TPACK framework as it describes the integration of technology into courses as a complex interrelation between content, pedagogy, and technology. I applied the framework to a professional development context and designed a 6-week professional development program for engineering faculty in India. As I wanted to understand the phenomenon of interest i.e., the development of TPACK in a professional development setting, I used a qualitative case study research as the methodological framework for the study. Multiple sources of data were collected using instruments that were aligned to address the research questions of the study. A thematic analysis approach was used to analyze the data as the study aimed to categorize the participants' responses into meaningful patterns that would illustrate their experiences during the 6-week professional development program. Relevant literature was cited throughout the study to showcase the necessary coherence with prior literature.

3.12 Summary

I designed this study of understanding the development of TPACK in a professional development context using the methodological framework of qualitative case study. Multiple sources of data were collected in the form of semi-structured interviews, reflection journals, and on-field observations during the 6-week program. I analyzed the data using a thematic analysis methodology to generate themes that describe different aspects of the participants experiences. I present the results of the thematic analysis in the next chapter.

CHAPTER 4. RESULTS

4.1 Introduction

The results of the thematic analysis are presented in this section as I characterized them into themes and sub-themes. Each of the themes are focused on a specific facet of the participants' experience during the 6-week professional development program. Illustrative quotes from the data sources are provided for each theme to give additional context. In total, four themes emerged from the data analysis process as mentioned below.

- Theme 1: Critical Reflection and Metacognition Necessary Skills for the Development of TPACK
- Theme 2: Low Technology Self-Efficacy Hindered the Usage of Technology Tools
- Theme 3: Community of Practice (CoP) Members with Varied Prior Teaching Experience Helped in the Development of Tacit Knowledge
- Theme 4: Shift in teaching philosophy from teacher-centric to student-centric approach

Theme 1 – Critical Reflection and Metacognition Necessary Skills for the Development of TPACK

In theme 1, I talk about the process of how the participants developed pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge. For effectively integrating technology tools into their courses, the participants needed to engage in critical reflection and develop a meta-conceptual awareness of how to use TPACK to address the learning needs of the students and the limitations of teaching in the traditional lecture-based format. Figure 8 illustrates the thematic development of theme 1 from the different codes and categories in the code book. The code intersecting TPACK sub-domains included quotes that described the instances when the participants reported to intersect their knowledge of the content, pedagogy, and technology to construct pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge. The codes "technology enhanced pedagogy" and "represent content" included quotes when the participants started to realize the affordances of technology tools and how they could use the tools to innovatively represent the course content and implement pedagogical activities that would help students in their learning process. The concept map was used a resource to help represent the construction of mental models and understanding the interrelation between the TPACK sub-domains.

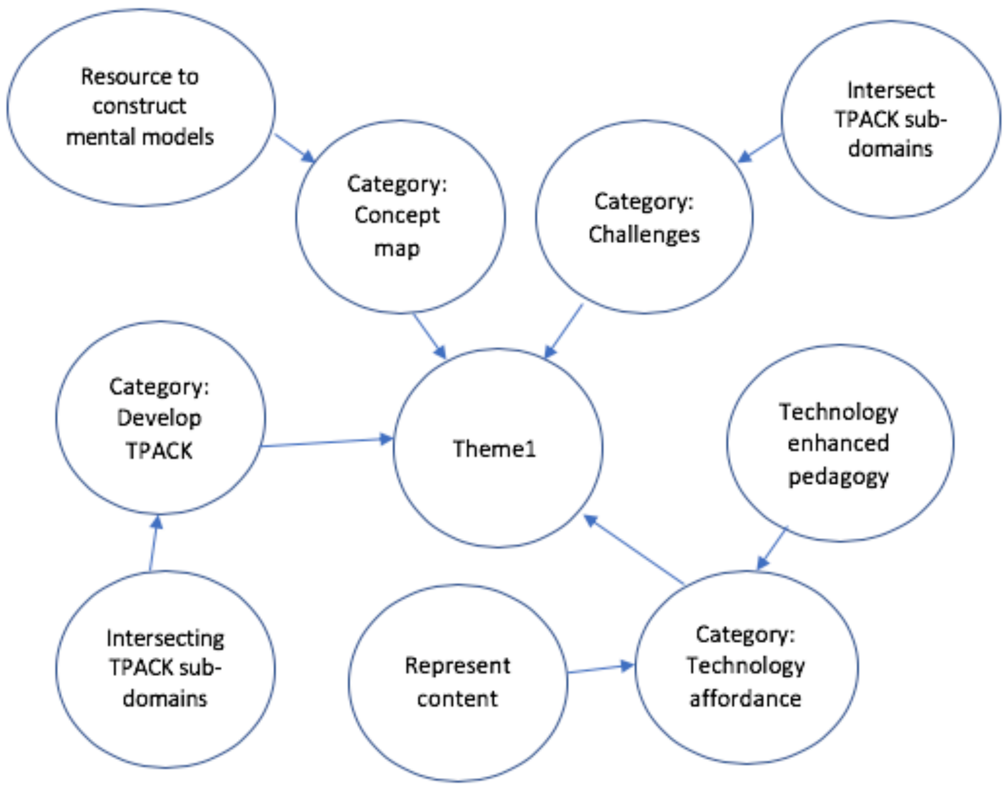

Figure 8 – Thematic mapping of theme 1

Theme 1 is structured by using two sub-themes as mentioned below.

- Sub-theme 1.1 – PCK, TCK, and TPACK constructed by engaging in critical reflection and forming mental models using the TPACK sub-domains
- Sub-theme 1.2 – TPACK developed by combining the knowledge of intersecting sub-domains to address learning needs of students and current limitations of instructors

Sub-theme 1.1 – PCK, TCK, and TPK constructed by engaging in critical reflection and forming mental models using the TPACK sub-domains

In this sub-theme, I present the participants' experiences as they intersected their knowledge of the basic TPACK sub-domains (content, pedagogical, and technological knowledge) to construct pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge. During weeks 2 – 6 of the professional development program, I provided the participants with multiple opportunities to develop knowledge of the intersecting sub-domains of TPACK i.e., pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge. On the day 3 of week 2 of the professional development program, I asked the participants to apply the learning from day 1 and day 2 to their respective courses. During days 1 and 2, I introduced the participants to Perkins's 7 principles of making learning whole, Chi's ICAP framework, and asked them to identify the difficult concepts and misconceptions for their course. Participants mentioned the following in their reflection journal on week 2:

> *"I feel the Perkins 7 principles are like an overall summary of the pedagogy. It was well presented with good examples and applications, and I am thinking how to apply it to my course."* (Participant 4)

> *"We have learned the Perkins 7 principles of making learning whole. It was clearly explained by [the facilitator] using Cricket example. Sufficient time was also given to us to implement the same [principles] within our courses to ensure effective teaching and learning process."* (Participant 6)

During weeks 3 – 6, I encouraged the participants to frequently construct mental models that would help them to think about how the TPACK sub-domains could be interrelated by situating them in the context of the classroom and learners. During the week 4 interviews, participants mentioned how they combined their pedagogical knowledge with their content knowledge of the course, and as a result developed pedagogical content knowledge. Participant 5 said,

> *"While I was aware of the methodologies and practices, I never thought about what [pedagogy] to apply where [content]. But now I'm able to have an understanding of how*

> *the different methodologies could be applied depending on the course and also the learners."* (Week 2 interview)

Many of the participants between week 2 and 4 identified some of the difficult concepts and misconceptions that students might have in their course. I noticed after speaking to the participants during the professional development sessions that they identified the difficult concepts and misconceptions by searching for existing literature. Few of them scheduled focus group discussions with students who have taken the course in the last couple of semesters.

> *"In the last two weeks, I was able to evaluate what could be the misconceptions for my course and then think about how I could clarify the misconceptions of my students."* (Participant 3 – week 2 interview)

> *"My past teaching experience helped me identify some of the difficult concepts and misconceptions for the course I am teaching."* (Participant 4 – week 2 interview)

> *"I interacted with students who have taken the course in the last academic year to understand some of the difficulties they encountered in the course. This helped me identify the difficult concepts of my course from the students' perspective."* (Participant 6 – week 2 interview)

After developing an understanding of some of the misconceptions that students developed and which content constituted as difficult concepts in the course, the participants started to intersect their knowledge of content and pedagogy and adapt the pedagogy based on the content:

> *"now I came to know the different teaching methodologies, what are the difficult concepts and misconceptions for the course, and how I should adapt my pedagogy to teach the difficult concepts and misconceptions"* (Participant 7 – week 4 interview).

Participant 6, for example, presented in one the sessions during week 2 of the program about the difficult concepts he identified for his course. I made a note of him mentioning that the internal working of an electronic machine was a difficult concept he identified, as it is challenging for students to visualize the whole process. I noted this observation, as he was the only participant in the program who immediately identified a difficult concept from his course. Participant 6 mentioned in his week 4 interview to include some laboratory sessions as part of his course schedule to help students visualize the internal working of an electrical machine.

> *"I have started to identify the difficult concepts and then identified pedagogy tools that will help students learn the concepts. For example, I plan to take students to the lab and show how an electrical machine works. I haven't done this in the previous semester."*

Participant 1 in her week 6 interview talked about how she intended to include authentic learning teaching practices by showing students the real-life application of the concepts she is teaching. She believed that the use of authentic learning could help in knowledge retention as the information is transferred to student's long-term memory.

> *"I can show students the examples of how buildings are constructed and then show them how certain calculations are required to develop the beams and structures. Also, if a calculation goes wrong, what kind of failures will take place. This will make them remember the concepts later, as I am asking them to apply the knowledge in a different scenario and connect the concepts to their long-term memory."*

During week 4, I asked the participants to start identifying technology tools that could be used to represent their course content in varied ways. During this process, the participants continued to form mental models by using their knowledge of technology and content and think about how the use varied representations could help the students learn in the course. Participants built the knowledge of how and why a certain course content should be represented in a specific way. They used pre-existing learning resources (which are available for free access) or developed new resources by using different software tools to represent some of the course content.

> "*In my course, there are a lot of topics which need visualization. So, to get students' attention and help them in visualizing certain topics, I thought I could use pre-existing*

> *videos and also develop some animated videos of my own.*" (Participant 5 – week 4 interview)

> *"I have also used the VideoScribe software to make videos for certain topics. I was unable to complete the video development, but I plan to complete it in the coming weeks."* (Participant 7 – week 4 reflection journal)

Participant 3 taught a course that required students to have high level of spatial thinking skills. She reported to provide students with animated videos which they could watch before coming to the classroom.

> *"Earlier we used to make solid modules in the course [freshmen engineering graphics] and we used the modules to teach concepts like front view, top view, and side view. But the complexity of spatial visualization increases as the course progresses. Now, I can ask students to watch animated videos about the solids before coming to the class. This makes my job of helping students visualize very easy."* (week 4 interview)

Participant 2 identified the course content that needed repetitive learning (a learning need of the course), and utilized some of the audio tools that were introduced to her in week 3 of the program to develop technology-mediated learning resources for the course. She believed that students can use the audio resources to access and listen to the content repeatedly:

> *"Few concepts which need repetitive learning… if we create audio files and share it with students, they can listen to them multiple times and do not have to keep accessing their class notes or the textbook."* (week 4 interview)

In week 5 of the professional development program, I asked the participants to identify technology tools that can be utilized to support some of the pedagogic techniques that they identified for their course in week 2. Similar to pedagogical content knowledge and technological content knowledge, the participants formed mental models on how different technology tools could be used to implement a specific pedagogic technique they identified. While forming the mental models, they were able to think about how the integration of the technology tools would help students learn in the course. Participant 7, who wanted to implement a flipped classroom approach for his course, used Edmodo, an online tool which could be used to share the course content with students prior to the start of the class:

> *"I wanted to implement the flipped classroom methodology in my class. Through Edmodo, I asked students to access the content for certain topics and then engage in discussions in the classroom."* (week 5 reflection journal)

Participant 5 identified technology tools to implement a similar flipped classroom approach and dedicate a certain number of classroom hours to facilitate discussions and clarify students' misconceptions in the course.

> *"I have used the flipped classroom approach. I have posted videos and content on the website, asked students to review them and then used the classroom time to engage in discussions and clarifying student's misconceptions."* (week 6 interview)

Participant 6 wanted to start discussions among students about the course content prior to the start of the class and wanted to include an online discussion forum to post questions for discussion:

> "*the discussion forum is helpful to encourage students to interact with peers and the instructor. I plan to post questions on the forum to start discussions among the students on different topics."* (week 6 interview)

Participant 4 used a social bookmarking tool to provide students access to supplemented content that is not available in the prescribed textbooks. Majority of the students in the institution who belong to the low-SES status primarily depend on the textbooks available in the library (an observation I made from the time I was working at the institution), and the use of such tools could help provide students open access to the additional course content.

> *"I have also used Diigo, which is a social bookmarking tool to provide additional information to students that is not available in the textbooks."* (week 5 reflection journal)

The participants mentioned to develop technology-mediated resources and provide students with asynchronous access to multiple learning resources outside of the classroom. The students have to currently rely on either the instructor, the textbook or their classroom notes for learning resources. Students who are unable to attend all the classroom sessions, and as a result have an incomplete set of notes, might encounter challenges to succeed in the course.

> *"I can record videos of my class lectures and share them with the students."* (Participant 2 – week 5 reflection journal)

> *"Using technology, my job could get easier. I realized with the course website, students can access the resources in my absence. Some of the students might not attend all the classroom lectures and if they miss an important topic, they could use the videos to make up for their absence. I can upload all the course content on the website and give access to the students."* (Participant 4 – week 6 interview)

Participants reported that by using technology tools in courses, they could now extend their interaction with students beyond the usual classroom hours. Participant 2, who developed a course blog with a discussion forum, mentioned how the course blog would enable students to interact outside the classroom. She mentioned that some of the students who do not participate in classroom discussions might be willing to communicate virtually.

> *"There is not enough time to have many discussions in the class. Some students might talk, and other might not talk. So, all this [student interaction] can be done over a course blog."* (Participant 2 – week 6 interview)

The same was reiterated by other participants as they used technology tools to extend student-student and student-instruction interaction outside of the classroom.

"I realized the website could be useful for both me and the students as it can help us to interact with each other. Not only while the students are in the institution, whenever they want to study or if they have any questions, they can post questions on the website." (Participant 1 – week 6 interview)

"Students can also collaborate with peers when at home through the website." (Participant 6 – week 6 interview)

"Students mentioned that for this course, they are able to interact more. This is good. I would like to have similar structure for other courses which could support students learning beyond classroom hours." (Participant 7 – week 6 interview)

Participant 2 believed the use of technology tools for student-student interaction might encourage students who are introverts to interact, as they might be hesitant to communicate with peers during in-person group discussions.

"When I shared with students, they were excited about the blog because they can now access it when they are at home and while they are going home. Some of the students who are introverts might not want to interact in a group discussion, but they might use the blog if the discussions are private." (week 6 interview)

Participant 1 mentioned that an online discussion forum could be used to encourage student collaboration during the final semester of their undergraduate program, as they are expected to develop engineering design solutions to some of the open-ended problems provided by their department:

"I interacted with students about their final project and I realized that if I develop a forum for students to share ideas, it might be helpful to them. They might benefit from interacting with each other and sharing ideas because they do not come to the institution and can't meet us in-person every day." (week 6 interview)

It is important to note that the interpretation of the participants constructing the mental models is an observation I made during the 6-week professional development program. Mental models are psychological representations of different elements and their interrelations in specific situations that individuals construct based on their prior knowledge and beliefs (Krauskopf et al., 2015). It was therefore difficult to provide evidence for the construction of mental models unless the participants explicitly mentioned them in the interviews or reflection journals. However, I aim to provide evidence for the formation of mental models by providing some of the concept maps that the participants developed during the 6-week program. The concept maps illustrated below provide a physical representation of the multiple mental models constructed by the participants. The concepts maps help us understand how the participants constructed mental models and interrelated their content, pedagogical, and technological knowledge. Each of the nodes in the concept map represent a specific aspect of the participants' knowledge of the TPACK sub-domains and the connections between the nodes highlight the reasoning behind why the mental model was formed i.e., how the connection between the nodes would help students in their learning process. The color codes to all the nodes were provided by the participants themselves. In Figure 9, the nodes colored in grey, blue, and pink represent the content, pedagogical, and technological knowledge of participant 3.

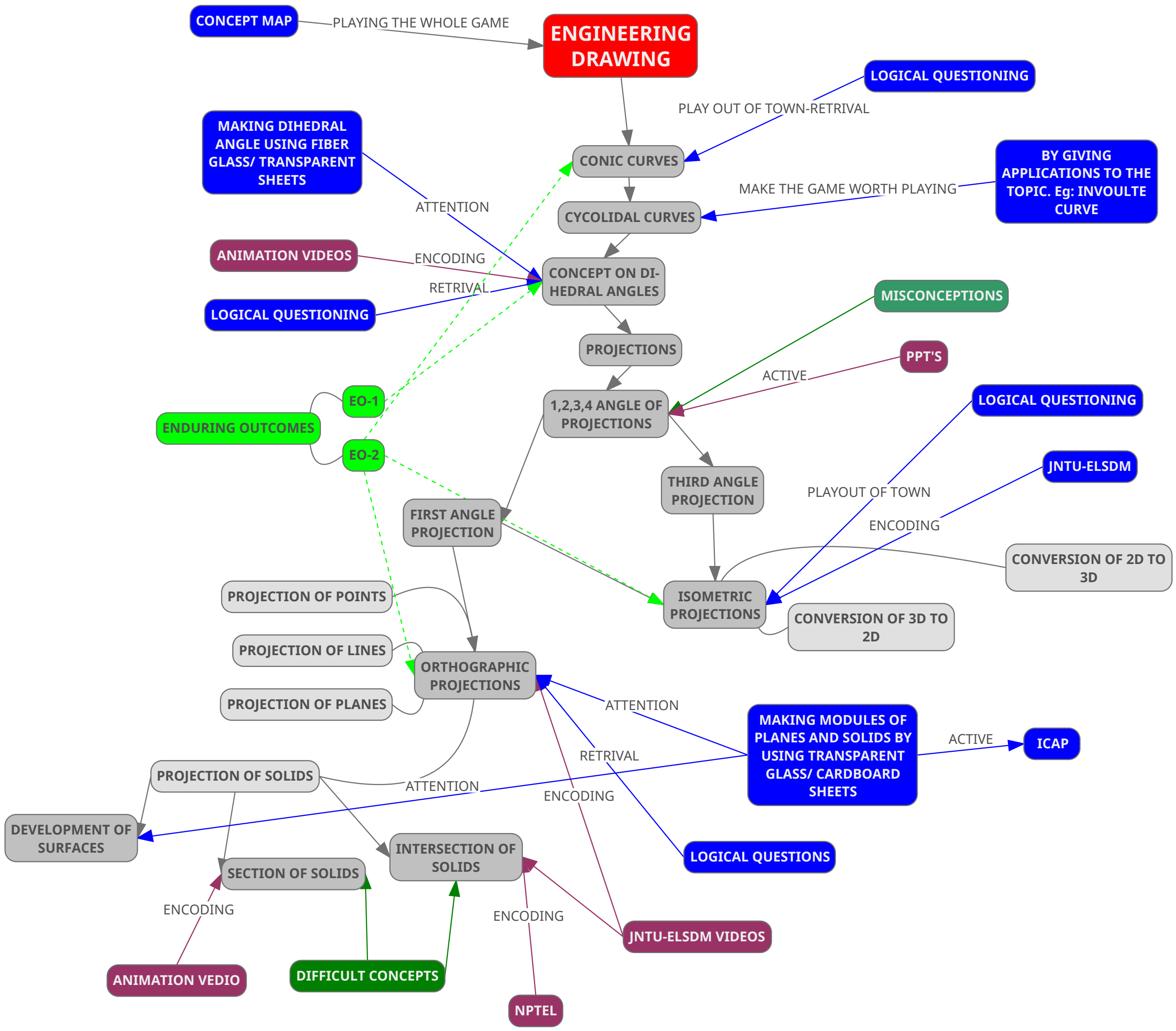

Figure 9 - Concept map developed by Participant 3

Figure 10 shows the concept map developed by participant 2. The nodes colored in blue, green, and purple represent the content, pedagogical, and technological knowledge of participant 2.

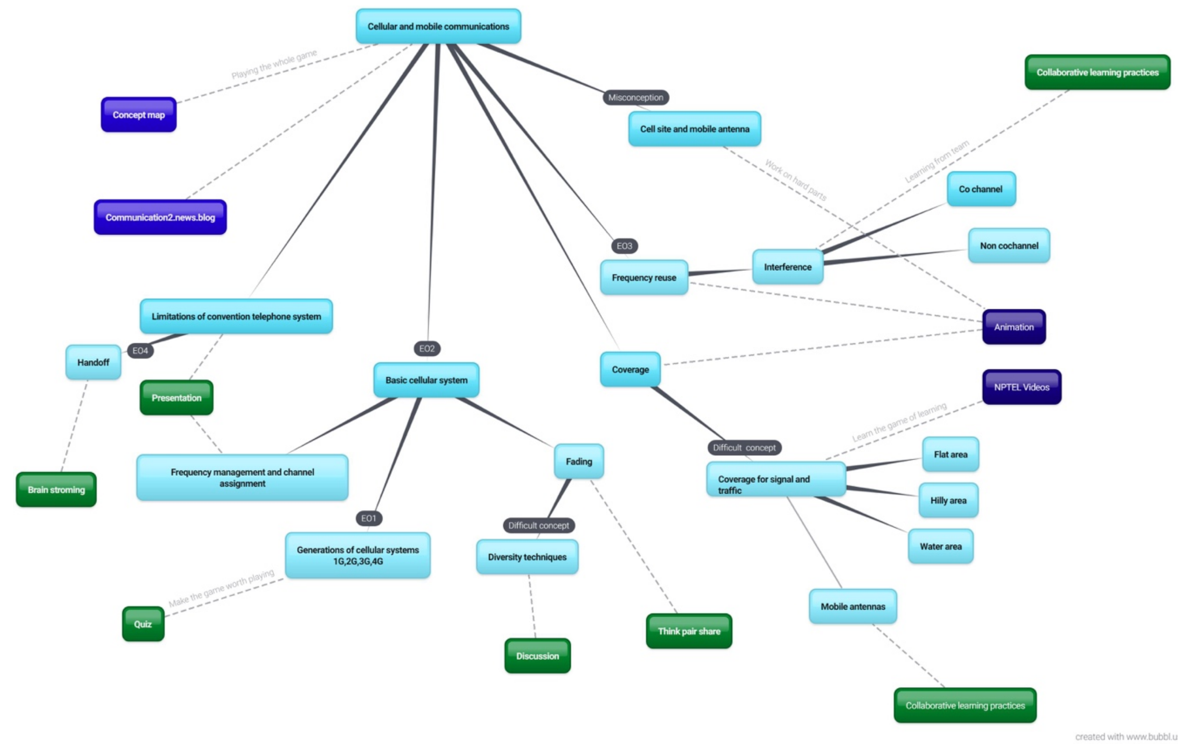

Figure 10 - Concept map developed by Participant 2

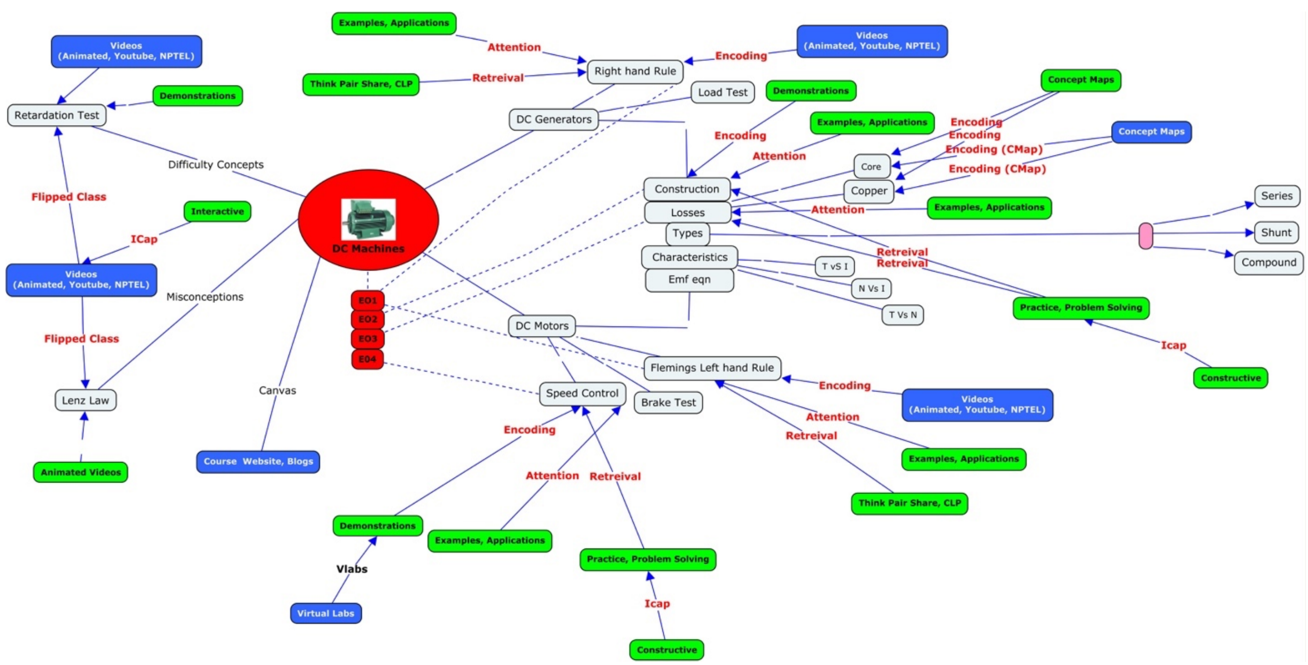

Figure 11 - Concept map developed by Participant 6

The white, green, and blue colored nodes in Figure 11 represent the content, pedagogical, and technological knowledge of Participant 6. Each of these three concept maps depict how the participants formed mental models to understand and make connections between their content, pedagogical, and content knowledge. The concept maps provide a big picture of how the mental models were constructed to benefits the students in their learning process and how the pedagogical and technological tools being used would help them achieve the intended learning outcomes of the course.

While the construction of mental models helped the participants develop the knowledge of the intersecting TPACK sub-domains, they initially encountered challenges while constructing the mental models. All of the participants individually (during the interviews) and collectively (during the professional development sessions) reported to face challenges while forming mental models using their content, pedagogical, and technological knowledge. This particular exercise was new to the participants and they struggled while working on it. All of the participants, for example, faced challenges during weeks 2 – 4 while they combined their content and pedagogical knowledge to develop pedagogical content knowledge.

> *"Difficulty was while applying Perkin's 7 principles to the course. I understood the principles but I am unable to apply it to my course."* (Participant 1 – week 2 reflection journal)

> *"Applying the Perkin's 7 principles is challenging because I am teaching this course for the first time, and I feel I don't have complete understanding of the course. To making the learning whole, I feel it is necessary for us to teach the course for a few times."* (Participant 2 – week 2 interview)

> *"Based on my prior knowledge, some activities seemed to be easy and some difficult. The ones that seemed difficult, I just need to take more time to reflect on it. For example, connecting Perkin's 7 principles to the content of my course was challenging".* (Participant 3 – week 2 interview)

> *"In the last session, I understood Perkin's 7 principles, but it was difficult to apply the principles to the content of the course."* (Participant 4 – week 2 reflection journal)

> *"I had problem in Perkin's 7 principle. I understood some parts of the principles, but I'm facing challenge while applying it to my course content."* (Participant 5 – week 2 reflection journal)

> *"When I was trying to connect Perkin's 7 principles to my subject, even though I have experience in using different pedagogic techniques, it is taking some time to really understand [how to map the principles to the course] because as we proceed with the sessions every week, we want to specifically connect to a topic or the subject. So, it took me sometime to connect the dots and apply the 7 principles."* (Participant 6 – week 2 interview)

> *"Working with the ICAP framework. I haven't included in the concept map yet, as I am still trying to figure out when I should use active, constructive, and interactive activities."* (Participant 7 – week 4 interview)

After listening to the participants' responses during the week 2 interviews, I introduced the process of concept mapping to help them with the process of forming the mental models and combining their knowledge of content, pedagogy, and technology. However, few of the participants continued to face challenges while forming the mental models and developing concept maps in the subsequent weeks.

> *"I felt very difficult in mapping content, pedagogy and technology. This is because I have never taught this subject and I have been developing the concept map just based on my experience as a learner i.e., when I took the course as a student few years back."* (Participant 1 – week 4 interview)

> *"During the last 4 weeks of the faculty development, concept mapping was the most challenging task. Because when I designed the concept map, I got confused a lot on which pedagogy technique should I use and to which course topic I should apply the technique."* (Participant 4 – week 4 interview)

> *"Everyone felt easy while developing the content part of the concept map. But when we had to map pedagogy and technology, we were little bit confused on how to corelate or integrate them. While we know about the different pedagogy methods... we are finding it difficult to make a decision of which method should be used for which concept and why. We might use an active learning technique, but it might not be best suitable for the content. This is one aspect which I feel many of us were having trouble understanding"* (Participant 6 – week 4 interview).

> *"sometimes when we are integrating technology with pedagogy, it might be very difficult as we have the experience of implementing certain pedagogical techniques in the classroom without the use of technology. But when it comes to using pedagogy with technology, it was difficult to integrate them."* (Participant 6 – week 4 interview)

Participant 7 also had trouble while forming mental models using technological knowledge due to their limited experience of using technology tools in courses. Although participant 7 had high technological knowledge prior to the start of the 6-week program, he was unable to comprehend the affordance of technology tools in relation to the course:

> "*the most difficult was making the connections between content, pedagogy and technology. Difficult because we were unaware of what kind of technology tools could be helpful in teaching*" (Participant 7 – week 4 interview).

I illustrate the initial and final version of the concept map developed by Participant 4 to provide evidence of the challenges they encountered while constructing the mental models. You will observe a lack of proper integration of content, pedagogy, and technological knowledge in the concept maps as the participants struggled to combine their knowledge of the TPACK sub-domains.

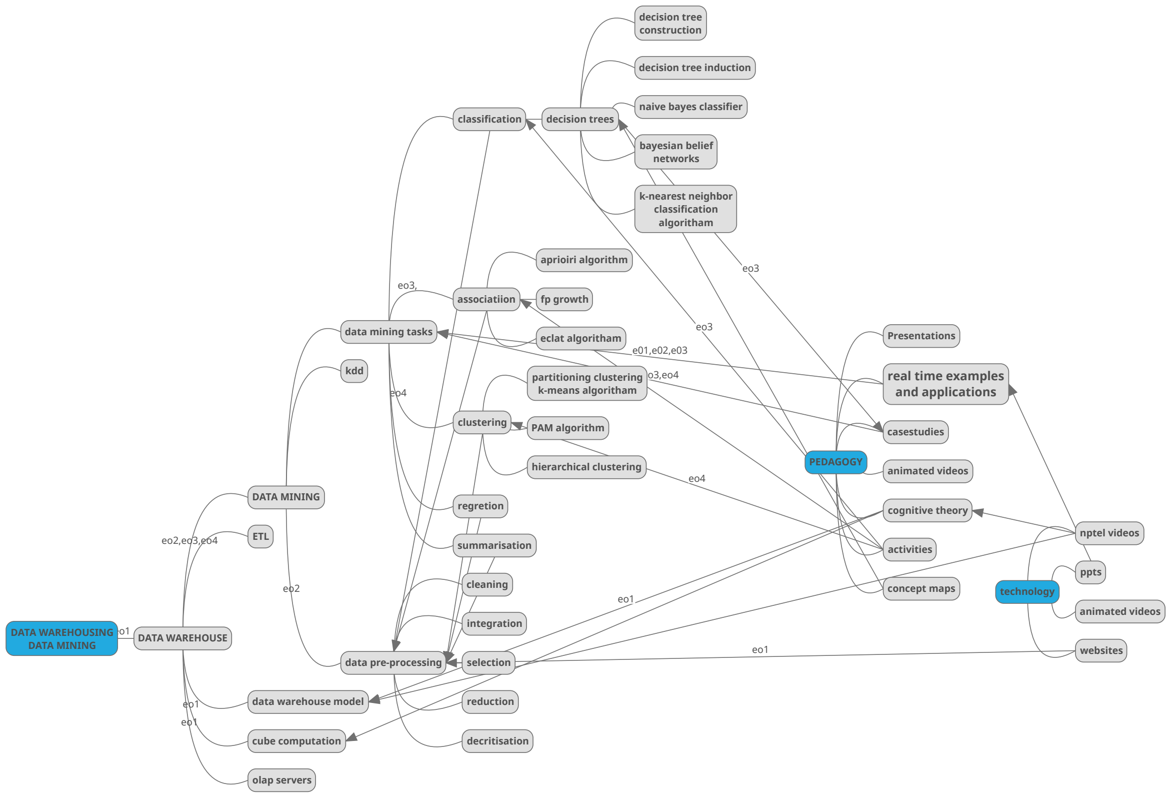

Figure 12 - Initial version of concept map developed by Participant 4

In Figure 12, participant 4 included his pedagogical and technological knowledge to the right of the concept map and was finding it difficult to understand why a specific activity or technology tools should be used for the course content. While making the connections, he did not clearly state the reasoning behind connecting two nodes. However, Figure 13 depicts the final version of the concept map developed by Participant 4. In this version, he color coded the different nodes by representing the knowledge of each sub-domain with a different color. He represented his knowledge of content using grey, knowledge of pedagogy using red, and knowledge of technology using pink. He also mentioned the rationale for each of the connections he made between the different nodes. This indicates how the participants initially encountered and later overcame the challenges while constructing the mental models.

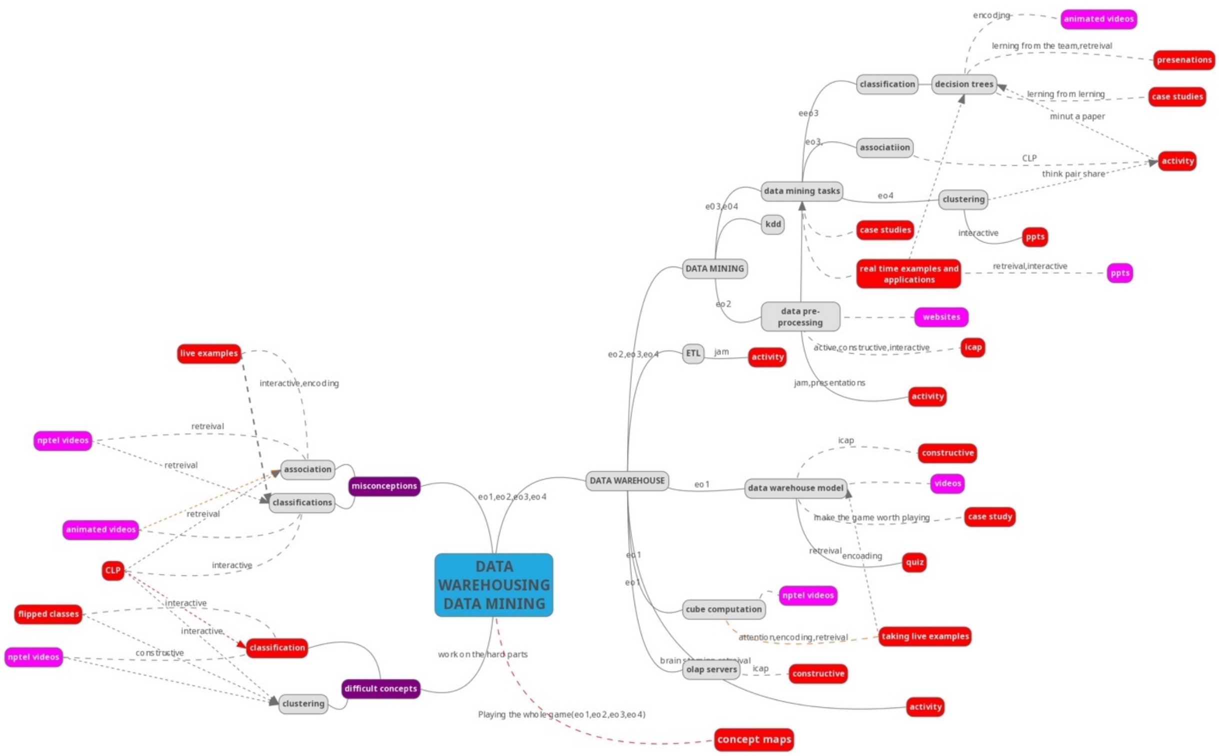

Figure 13 - Final version of concept map developed by Participant 4

The participants encountered challenges while constructing the mental models as they were unable to critically reflect and understand how the use of a specific pedagogical technique or technology tool would help students learn the course content. However, the participants through the professional development program started to reflect on their prior teaching experience and ask themselves critical questions. While the participants engaged in critical reflection, they recognized some of the limitations they might have previously faced while teaching in the traditional lecture format. Participant 5 said,

> *"I also realized that by using the chalk and talk method, you can't teach all the content. For example, a magnetron, I can't explain the concepts and functioning of magnetron using chalk and talk."* (week 6 interview)

Another participant mentioned similar experience when she struggled to teach concepts from her engineering graphics course without the use of a physical artefact. This course required the students to build spatial thinking skills, which the participant mentioned was difficult to achieve in a traditional lecture format classroom.

> *"Engineering graphics is the course I selected for this faculty development program. This course is generally challenging for me, as I don't have any physical artifacts that I could use to help my students understand the course content. When I ask students to visualize the front, top, and side view of a 3D figure, it is challenging for some students who have low level of spatial thinking skills"* (Participant 3 – week 4 interview)

While reflecting on their prior teaching experience, participants recognized the lack of alignment of technology with the pedagogy and content:

> *"Earlier in the last 10 years, I taught most of the content using the traditional chalk and board method. The alignment of content with the pedagogy was missing"* (Participant 4 – week 2 reflection journal).

> *"Previously I used to implement different pedagogical techniques without understanding why and when they should be used"* (Participant 6 – week 4 interview).

> *"In the traditional teaching approach, we never done such a process. We treated content, pedagogy and technology as three different things and never tried to effectively connect or compliment them in a way to best help the students achieve the learning outcomes of the course"* (Participant 5 – week 6 interview).

> *"as with my prior experience, I did not focus on the combining the three things [TPACK sub-domains]. I individually looked at the content and only used technology to create PowerPoint presentations. It was just like how we were teaching on the blackboard, we transferred the same content to the presentation without really understanding why we are doing it"* (Participant 7 – week 6 interview).

The participants, as shown, started to build critical thinking skills and were able reflect and understand how the affordances of various pedagogy and technology tools could help students learn the course content. The development of critical thinking skills therefore helped the participants in the formation of mental models and construct pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge.

Participants during week 3 and week 4 were encouraged to use concept mapping tools to help them form mental models. None of the participants used any concept mapping tools before and benefited from the experience. Participants reported the concept mapping experience to help them to represent the interrelation between their knowledge of content, pedagogy, and technology.

> *"Now [after developing the concept map], I can understand what the difficult concepts and misconceptions are for my course and how I can use that knowledge along with my knowledge of pedagogy and technology."* (Participant 1 – week 6 interview)

> *"While I was developing the concept map, I got a lot of clarity on where and how to apply these different pedagogical techniques. The working document helped me individually reason out how to apply the principles and the ICAP framework, and the concept map helped me integrate them to my course content."* (Participant 3 – week 4 interview)

> *"Perkin's 7 principles, we did not know how exactly we should map the principles. But while developing the concept map, we got a broad overview of the content and that helped us making those connections based on the content of the course."* (Participant 6 – week 4 interview)

> *"While working on the concept map, I was able to reflect on which pedagogical technique should be used for which content of the course and why."* (Participant 7 – week 3 reflection journal)

Participant 1 mentioned that the concept map helped her in aligning the course content with the enduring outcomes and then identifying pedagogy and technology tools to help students in their learning process:

> *"By developing the concept map, I now have a very good understanding on how the course should be structured, how the course content should be designed to meet the enduring outcomes, and what kind of pedagogic methods and technology tools I should use to help students achieve the enduring outcomes"* (Participant 1 – week 6 interview).

Sub-theme 1.2 –TPACK developed by combining the knowledge of intersecting sub-domains to address learning needs of students and current limitations of instructors

In this sub-theme, I describe the process of how the participants developed and utilized TPACK in their respective courses. By end of week 6 of the professional development program, many of the participants neared the completion of their final design project. During this process, the participants developed a meta-conceptual awareness of how to utilize the knowledge of each of the intersecting sub-domains (pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge) to address some of the limitations they encountered as an instructor and the learning needs of students.

For example, participant 2 developed a blog for her course to share the content, which needed visualization, and mentioned it to be one of the limitations of teaching that particular course in a traditional lecture format. She developed a course blog by combining her technological content knowledge and technological pedagogical knowledge to provide students with a designated platform to access all course related content.

> *"The content in my course is about mobile communication where there are a lot of topics which students need to visualize. I cannot help them visualize the content without taking them to a base station and also cannot physically show them how the signals are travelling. But I can do all that showing them videos where I can explain the concepts through visual animations. All this additional content could be shared to the students over a blog… so I went ahead and created a course blog."* (week 6 interview)

Another challenge that most of the participants encountered is the limited classroom hours. Participants while developing technological pedagogical knowledge evaluated ways where they could support and facilitate students' learning outside of the classroom. They combined their technological pedagogical knowledge with the other intersecting sub-domains and developed a course website that could be used to provide students with access to additional learning resources.

> *"In the class, we just have 50 minutes and it is difficult to teach and ensure students' learning in that time. Using technology, we can think about how we can support students' learning outside the classroom. Through Edmodo, I have conducted quizzes to make students retrieve information from their long term memory. To conduct quizzes, I taught a particular topic to the students and asked them to submit the quiz by accessing it on the website after class"* (Participant 7 – week 6 interview).

> *"Most of the time, students' learning or access to resources is limited to the classroom. Through the course website, students will be able to access the resources outside the classroom. Students can also collaborate with peers when at home through the website. I reflected on my limitations to teach in the classroom and wanted to support students learning outside the class."* (Participant 6 – week 6 interview)

Participant 3 combined her knowledge of all the three intersecting TPACK sub-domains to develop a course website where she could provide students with additional examples of problems she was unable to teach before (a challenge she encountered in the previous mode of instruction).

> *"Previously, the content I taught was limited to the content available in the text book. Now, I am able to provide students with content outside of the text book. Before, I used to ask students to take notes in the classroom and I would explain to the students by providing them one example. Students' learning would be then limited to that one example and they would not practice any additional problems that are not very similar to one's solved in the classroom. Now, in the classroom, we are focusing on the textbook examples and I am able to provide additional examples through the website. I did not have enough time to do all*

this in the classroom before, but now by using technology, I can prepare additional content to support students' learning outside the class. Right now, more than 50% of my students are actively accessing the website and using the content." (week 6 interview)

Participant 4 combined his pedagogical content knowledge and technological pedagogical knowledge to effectively manage the content in limited classroom hours. He identified topics that students could learn by themselves and provided them access to that content through a course website.

> *"First step is explaining the algorithm and then solving a mathematical problem by applying the algorithm. Previously, one topic would take 3-4 lecture hours. Now, I can reduce the time to 1-2 hours by asking students to learn the algorithm before coming to class. This way I could focus my time to teach them the application in class."* (week 6 interview)

While working on the final design project, participants took the learning needs and individual differences of the students into consideration. Participant 2 observed that some of her students were not comfortable asking questions in the class. She combined her pedagogical content knowledge and technological pedagogical knowledge to develop a course blog and encourage some of those students to interact virtually:

> *"There are certain topics in the course where students might build some misconceptions. Like the elevation angle. Not all students will ask questions during the class, as some students might be shy and don't ask questions. Usually most students don't prefer to ask questions in the classroom. However, if I ask them to ask questions through a discussion forum, then many students might do it because the students like to communicate over online platforms."* (week 6 interview)

All the participants used their technological pedagogical knowledge to integrate some kind of online discussion forums in their course website to extend student-instructor and student-student interactions outside of the classroom (a limitation in the current mode of instruction). Participant

1 mentioned that using a discussion forum can help both her and the students in the course. As an instructor with no teaching experience and intermediate content knowledge, she wanted to use the discussion forum to answer students' questions that she might not be able answer during the class (fulfilling her responsibilities as an instructor):

> "*I realized the website could be useful for both me and the students and can help us interact with each other. Not only while students are in the institution, whenever they want to study or if they have any questions, they can post questions on the website. If some students might feel uncomfortable to talk in class, they can have a conversation on the discussion forum available on the website. If I do not have an answer to a question asked in class, I can check with the other faculty and respond to the students question later on the website."* (week 6 interview)

Participant 6 combined his pedagogical content knowledge and technological pedagogical knowledge to include a discussion forum on the course website to post questions for specific topics and initiate interaction among students prior to the start of the class.

> *"I have included a discussion forum on the course website. The discussion forum is helpful to encourage students to interact with peers and the instructor. I plan to post questions on the forum before the class to start discussions among students on different topics."* (week 6 reflection journal)

Participants were observed to combine the knowledge of all the three intersecting TPACK sub-domains to develop technology-mediated resources that could be used to increase student attention and motivation in the course. Participant 1 who planned to use authentic learning activities (pedagogical content knowledge) in the classroom reported to wanting to use technology-mediated resources (technological content knowledge and technological pedagogical knowledge) to teach students few concepts using real-time simulations and, in the process, increase their interest in the course:

"If I can find content that students might find more interesting, they will also encourage their peers to use the content available on the website. I can do this by developing videos that would show students the real-time application of certain topics. For example, I can show students some examples of how buildings are constructed and then show them the calculations that are needed to design the beams and structures, and how if a calculation goes wrong, there would be different type of failures" (Participant 1 – week 6 interview).

Participant 5 mentioned to previously use hand gestures to teach few topics and believed the use of videos could improve students' motivation in the classroom.

"Now with technology it is easier to teach and keep students motivated because previously to make students understand something, I used my hand gestures. But that is not always helpful to the students and some might not find that interesting. Now with these videos I collected, I am sure I can get attention of more students in the classroom. Now everyone will find this course interesting." (week 6 interview)

The participants, to develop TPACK, combined their knowledge of the intersecting TPACK sub-domains while working on the final design project and adopted a technology-enhanced instruction that would help students in their learning process. Participants, while working on the final design project, used the final version of their concept map as a design prototype of what they would be developing for their final project. In the concept map, the participants included the course content, linked them to the course outcomes, and listed all the learning activities and technology tools they plan to implement and use in their course.

"I used the concept map as a prototype for the final project. After developing the concept map, I looked at how I can utilize the pedagogical methods and technology tools mentioned to teach the content in the course." (Participant 4 – week 6 interview)

"I was confused in the first few weeks, but in the later part I developed a concept map through which I got a clear idea about what I should be doing for the final project. The concept map served as a prototype, which I used to complete the final project. It helped me

understand how I could integrate content and pedagogy effectively with technology tools." (Participant 6 – week 4 interview)

Theme 2 – Low Technology Self-Efficacy Hindered the Usage of Technology Tools

In theme 2, I present some of the challenges that the participants encountered as a result of low technology-self efficacy. Participants with low technology-self efficacy were observed to be hesitant while exploring and integrating technology tools into their courses. They encountered trouble-shooting errors while utilizing the technology tools and sought help from their peers. Participants who were teaching courses in the computer science and engineering departments had high technology self-efficacy and were observed to support the other participants during the 6-week program. Figure 14 illustrates the formation of theme 2 from the various codes and categories in the codebook.

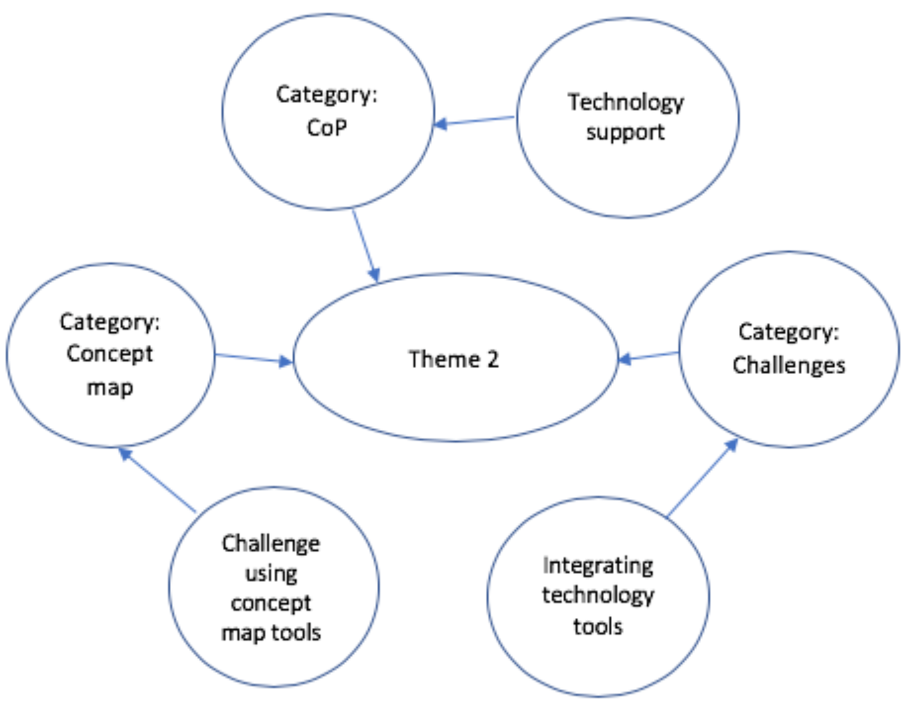

Figure 14 -Thematic mapping of theme 2

During weeks 3 – 6 of the professional development program, participants were encouraged to develop a concept map for their respective courses. The concept mapping activity was aimed to help the participants form mental models using the basic sub-domains of TPACK. I noted during my observations that all of the participants except Participants 4 and 7 were hesitant to use the concept mapping tools that were available online. Participants started to develop the concept map by drawing it manually on a paper.

> *"While developing the concept map, I found it difficult to use the online software's as I have never used it. I wasn't sure if the nodes could be moved or dragged and I thought the structure will be developed by the software."* (Participant 1 – week 4 interview)

> *"When used the mind mapping software, first I mapped the content. I was confused while developing the concept map for pedagogy and technology. It was a new tool for me, so while learning to use the tool, I had some trouble."* (Participant 3 – week 3 reflection journal)

> *"It was just normal. I selected one of the available free software's and started using it straight away. It took a little time to look at all the features available, but it was not difficult."* (Participant 4 – week 4 interview)

> *"It was challenging to start using the mind map software." (*Participant 5 – week 4 interview)

> *"One challenge was using online tools to develop the concept map. Technology makes our job easier, but we need to be aware of the tools and know how to use it. So in the beginning, everyone would be hesitant to use it. Before I started using the mindmeister tool, I first drew the concept map on a paper. Once I developed the first draft, I then used mind map tool to draw the concept map."* (Participant 6 – week 4 interview)

Only after I explicitly insisted on the use of the concept mapping tools that are available online, participants slowly started to explore the concept mapping tools that were online. Once they started to use some of the available tools, they perceived the tools to be user friendly. Participant 2 said,

> *"I had difficulty in using different software's for concept mapping as I thought it is going to be a complicated task. So I developed the concept map in a word document, but then I realized the concept map is not efficient and the map was confusing. I later looked at tutorials for some of the softwares and realized they are easy to use."* (week 4 interview)

When asked during the week 4 interview if they would now (after using one of the online tool) take a different approach to developing a concept map, Participant 6 agreed and said that he would start by using the mindmeister tool as he now knows how to use it and is aware of the different features available with the tool.

> *"Now that I know to use the tools, I will directly start developing the concept map using the tool instead of first drawing it on paper."*

Participants also encountered challenges while identifying the necessary technology tools that they could use to complete their final design project. During weeks 3 – 6, I asked the participants to explore the different technology tools that could be used to represent the course content and help facilitate some of the pedagogic techniques they planned to implement in the course. All of the participants (expect Participants 4 and 7) did not have a good awareness of the different tools available to develop a website. I noticed during my observations that both Participants 4 and 7, who are from the computer science and engineering department, were able to quickly decide which platform they would use to develop and host a website. When I checked with them during the week 5 sessions, both of them mentioned to have developed the necessary knowledge while teaching students different courses on website development.

Participant 2 mentioned to have trouble in creating a blog due to the lack of technological knowledge.

> *"looking at what technology tools should we use for course was challenging. This is something which is still not clear to me. In order to implement those things, we should have the knowledge. For example, if we want to implement a blog for the course, we need to*

> *know how to create a blog and also make sure the design is efficient for students to learn."* (week 6 interview)

Participants also reported to face challenges while implementing the technology tools into their courses. Majority of the challenges were technical issues that aroused while they were working on their final design project.

> *"When I started using the canvas platform, I had trouble navigating and using it. For example, I wasn't sure how I could upload the data and also what kind of data can I upload"* (Participant 1 – week 6 interview)

> *"Once I started working on it [final design project], it was difficult as it was the first time I am developing a blog. I had trouble creating a place for discussion with students. I also had many troubleshooting errors in the process."* (Participant 2 – week 6 interview)

> *"I was very clear about what content I should upload on the website, and how students will use the content, but development of the website was a challenge. For example, how to add students to the website, how to edit content, these were some of the difficult tasks."* (Participant 3 – week 6 interview)

> *"I started first by creating a blog. Then I tried using the Wix platform and found that I cannot share videos through Wix. The I tried platforms such as Adobe, Edmodo but I found it difficult. It is not user friendly."* (Participant 5 – week 6 interview)

> *"Usage of technology tools was a challenge. Even while using the website, I had trouble getting my students access the website. There were some technical issues."* (Participant 5 – week 6 reflection journal)

> *"when we are using the technology for the first time, whatever maybe the task, it seemed difficult to use as I was new to the tool."* (Participant 6 – week 6 interview)

> *"Technology usage was one of the challenge as I was new to using most of the tools. I needed to know how I could use the different tools."* (Participant 7 – week 6 interview)

However, participants did not mention any key issues while identifying the pedagogy tools for their courses. Their initial hesitancy in using the online concept mapping tools and while identifying technology tools could be a consequence of the low technology self-efficacy of the participants. Participants 4 and 7 who teach courses in the computer science and engineering department had no challenges while using the technology tools. The participants reported to seek support from Participants 4 and 7 while identifying and using technology tools for their course.

> *"Participant 6 gave me ideas on the different things I can do using technology. For example, show videos from M-tutor [externally developed animated content] and NPTEL videos [open-access videos of engineering concepts developed by instructors from IIT's], and record videos of derivations of a topic and post it. So, this way I started thinking about what I could do."* (Participant 1 – week 6 interview)

> *"One instance, I wanted to download some videos, but the website wasn't allowing me to do that. [Participant 7] told me about a software which will help me download. I also discussed with him about using audio tools in my class, because he was using them for his course. Just interacting with some of my peers helped me a lot."* (Participant 2 – week 6 interview)

> *"it was a new experience for me to create a website. Every time I had any challenge, I took help from my co-participants to solve some of the issues."* (Participant 3 – week 6 interview)

> *"We explored multiple tools as our peers were using different tools and we could all share our experience. While were doing this, we learnt how to use various technology tools and also the multiple features provided by the tools."* (Participant 6 – week 6 interview)

Theme 3 – Community of Practice (CoP) Members with Varied Prior Teaching Experience Helped in the Development of Tacit Knowledge

In theme 3, I talk about how the participants used their prior teaching experience to engage in reflection and received from the members of the community of practice. The development of TPACK as presented in theme 1 required the participants to build critical thinking and metacognition skills. Both of these skills are considered as tacit knowledge which cannot be easily taught to the participants. The participants reported to benefit from the diversity (in terms of prior teaching experience) among the community of practice members as they could help each other build the tacit knowledge while working on their final design project. Figure 15 illustrates the formation of theme 3 from the various codes and categories in the codebook.

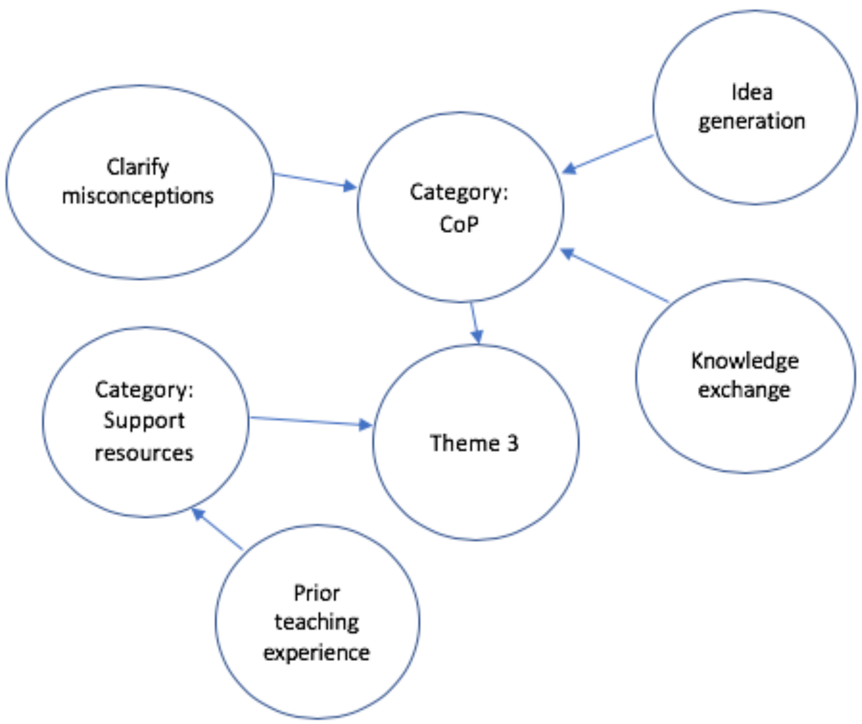

Figure 15 – Thematic mapping of theme 3

Theme 3 is structured by using two sub-themes as mentioned below.

- Sub-theme 3.1 – Prior teaching experience used as an internal support mechanism while engaging in reflection

- Sub-theme 3.2 – Community of Practice helped in generation of ideas, clarifying misconceptions, providing feedback, and enabled the exchange of knowledge

Sub-theme 3.1 – Prior teaching experience used as an internal support mechanism while engaging in reflection

Participants in their interviews mentioned that they often reflected on their prior teaching experience as they were redesigning the course by using technology tools. When they wanted to take the learners into consideration, they often resorted to their prior experience with teaching the course.

> *"I feel that is a benefit I have with my prior experience as a teacher. When you ask us something in the session, I can reflect back and think about how my students learned in the course."* (Participant 3 – week 2 interview)

> *"While working on the final project, I was aware of students' attitudes and motivation in the class. I was also aware of the students who are slow learners [lower performing students] and fast learners [higher performing students]. Through my past experience, I have learnt to use different teaching strategies to teach different students. For slow learners, I need to provide detailed explanation and then give them many opportunities to practice."* (Participant 4 – week 6 interview)

> *"My prior teaching also helped me reflect on how students learn. Which students are not interested in the classroom and how different students might learn the course content."* (Participant 5 – week 2 interview)

> *"The alignment between content, pedagogy, and technology is dependent on how well you can reflect on your course by taking your learners into consideration."* (Participant 6 – week 4 interview)

> *"I am able to reflect on my students experiences and identify the individual differences."* (Participant 7 – week 2 reflection journal)

Participants used their prior experience to reflect on how students have learnt the course content in the past and evaluated what topics were perceived as difficult, what topics needed alternate representation, and what topics needed to be taught using different pedagogies.

> *"My prior experience made it easy to identify the content that might be difficult for students to learn. This helped when I was developing the concept map. This also helped when including the content for the website."* (Participant 3 – week 4 interview)

> *"Prior teaching experience helped me while I was figuring out the misconceptions and difficult concepts for the course."* (Participant 4 – week 2 interview)

> *"When I had to include the pedagogic techniques and map them to the content, I was constantly reflecting on how my students learnt in the past offering of the courses."* (Participant 4 – week 4 interview)

> *"Prior teaching experience helped in identifying the misconceptions and difficult concepts for the course."* (Participant 5 – week 2 interview)

Participant 2 who is teaching the course for the first time recognized the importance of prior experience while combining her knowledge of content and pedagogy.

> *"As this is the first time I am teaching, my prior teaching experience did not impact a lot. However, if I had taught the course before, I could have done a better job at the concept map. I would have known which topic would need more emphasis for students to understand and which pedagogy I should use for a certain concept."* (Participant 2 – week 6 interview)

Participant 7 mentioned that his prior teaching experience helped him identify appropriate pedagogic techniques for his course.

> *"My experience with using different techniques before helped me to reflect on what should be the most suitable activities for my course. That experience helped me while developing the concept map."* (week 4 interview)

Participants' prior teaching experience helped them make faster connections between the three TPACK sub-domains while working on the final design project. During week 3, participants were identifying the different pedagogies that could be used to teach the course and Participant 6 said,

> "*my prior experience with respect to the content made it easier to relate [pedagogy] within a short time. Maybe if I am teaching for the first time, it will be difficult to correlate to which topic a particular principle could be applied.*" (Participant 6 – week 4 interview)

> *"My prior experience helped me to start making the connections between content, pedagogy and technology quickly as compared to the other participants. Especially the part of integrating technology"* (Participant 7 – week 4 interview)

Participants therefore depended on their prior teaching experience to regularly reflect and take students perspectives into consideration while developing the various constructs of TPACK.

Sub-theme 3.2 – Community of Practice helped in generation of ideas, clarifying misconceptions, providing feedback, and enabled the exchange of knowledge

A CoP was established prior to the start of the professional development to foster a collaborative learning culture among the participants. I noticed from week 1 that the participants started to regularly interact with each other while collaborating on activities, engaging in group discussions, and when providing peer feedback. From week 3 of the professional development program, participants started to explore ideas for their final design project. To instill a collaborative learning culture, participants were encouraged to consistently share their ideas with each other at the end of each day.

"He [Participant 4] helped me by showing the example for his own course and that gave me some ideas for mapping. After talking to him, I feel a little more comfortable in developing the concept map." (Participant 1 – week 4 interview)

"In the last two weeks, I got a lot of assistance from the other participants. They gave me many ideas for my final project." (Participant 2 – week 6 interview)

"While we kept discussing our ideas for the courses, we were able to share our inputs and I was able to take some ideas from the peers." (Participant 3 – week 4 interview)

"The regular interactions in the program helped me get new ideas from the other participants. As we are sharing the ideas, we talk about how we are connecting the learning to our own courses. So that really helped me during the sessions." (Participant 6)

The exchange of ideas was perceived to be helpful by the participants as it helped them overcome barriers that were hindering the progress of their final design project. Participant 1 who had trouble conceptualizing her final design project received help from Participant 6, which helped her narrow down ideas for the final design project.

"The first challenge was deciding about the final project. I wasn't able to think in a way to bring all aspects of the concept map together. When I spoke to [Participant 6], he showed me all the websites that are available and could support interaction between instructor and peers. I then narrowed down on the platform which I thought was most user friendly." (week 6 interview)

The collaborative activities helped the participant 4 to keep up with the learning in each session.

"*You have made us do activities in every session. While doing the activities I am able to share what I am learning and also learn from the other participants. This helped me keep up with the sessions."* (Participant 4 – week 2 interview)

The inclusion of collaborative activities could help the facilitators during professional development programs as they cannot always provide personalized support to every participant in the limited time available. Participant 2 believed the diversity in participants' prior teaching experience and engineering discipline helped in receiving valuable inputs from the CoP members.

> *"The participants in the sessions have different prior experience. So we get good feedback and valuable inputs from everyone. And also having everyone from different departments gave good insights during the sessions."* (week 6 interview)

Participants with high teaching experience benefited from the diversity in the range of CoP members' years of teaching experience. Participant 6 who had extensive prior teaching experience saw a lot of value in his interactions with the other participants with relatively lower teaching experience:

> *"Through the community of practice, I was able to get good inputs from the faculty with lesser teaching experience. Because experienced faculty will always be using the same approaches [pedagogic techniques] they used previously and might limit it to that. But the less experienced faculty would not have such limitations. They are more willing to explore as many tools and methodologies possible and evaluate what is best suitable to their course. Less experienced faculty are also closer to their own experience as students, so they are in a better position to understand what is best for the students, as compared to an experienced faculty like me who has not been a student for more than 10 years. So the mixture of having instructors with diverse teaching experience was helpful to my learning."* (week 6 interview)

The diversity in participants' discipline of engineering was also perceived to be beneficial by the participants as they could now observe the variation in the utilization of TPACK depending on the course.

> *"The presentations of our work at the end of each day was helpful. I was able to see how the other faculty integrated technology in different ways based the course they were teaching"* (Participant 4 – week 6 interview)

The participants used the CoP members as a feedback providing resource during the professional development sessions. While the process of providing and giving feedback started from the week 1, I observed that the frequency increased in the latter half of the program. When working on their final design project, it was observed that participants often received critical feedback on their design choices.

> *"By listening to my peers and also sharing my concept map, I was able to get a lot of constructive feedback on where I should improve. Sometimes the appreciation I receive from my peers boosted my morale."* (Participant 4 – week 4 interview)

> *"We started asking ourselves, "why a certain method should be used for a certain concept". While I was discussing with my peers, I was able to identify some techniques which were not appropriate for the choice of content."* (Participant 6 – week 2 interview)

> *"When I was identifying the pedagogy and technology tools, my peers gave me constructive feedback about my choices and this helped me improve my project."* (Participant 7 – week 4 interview)

Participants mentioned that the CoP members helped them clarify some of the misconceptions they might have developed during the sessions.

> *"Even when I was developing the concept map, I was new to the technology tool and many of them helped me identify some of my misconceptions. They used to point out if I misunderstood a certain concept and helped me correct the same."* (Participant 3 – week 4 interview)

"A lot of times, when the other participants presented their ideas, how they are applying the different concepts to their courses, it helped me clarify my misconceptions. For example, I had some questions about the application of the Perkin's 7 principles to my course. When I saw the presentation of other participants, I realized that my understanding of two of the principles was incorrect" (Participant 4 – week 4 interview).

"Articulation of the concept map. By discussing with the peers and discussing with you [facilitator], I was able to clarify my doubts." (Participant 7 – week 4 interview)

Participant 5 while conceptualizing her final design project reached out and sought help from the other participants even outside of the professional development sessions.

"I was meeting with other participants whenever I was working on the final project. Not only when we met for the sessions every week, but we also interacted when we needed help. I was discussing with [Participant 2] on what should be our final project. Sometimes we disagreed but it was a good discussion. Everyone in the group was involved to integrate technology and this reflected on our final projects." (Participant 5 – week 6 interview)

Participants used the CoP to exchange their knowledge of the basic sub-domains of TPACK. The exchange of knowledge took place across participants who had extensive and limited prior teaching experience. Participant 4, while developing pedagogical knowledge, interacted with the other participants who had previously used active learning pedagogic techniques in their course:

"I wasn't aware of techniques such as flipped classroom where students will first review the content at home and I could spend the classroom time to clarify their questions. I came to know about such approaches when I spoke to my peers, especially the ones who implemented such techniques before." (week 4 interview)

During week 4 of the professional development, participants started to intersect the knowledge of the three TPACK sub-domains. Participants mentioned the interaction with CoP members helped them to overcome the challenges they encountered while forming mental models.

> *"At the start, I first developed the content part of the concept map. Later, after discussing in groups, I came to know how to map pedagogy to content, and technology to pedagogy."* (Participant 4 – week 4 interview)

> *"I got over my challenges with applying Perkins 7 principles when I discussed about the principles with my peers."* (Participant 2 – week 4 interview)

Participants 6 and 7, during one of the report out sessions, presented how they integrated their knowledge of content and pedagogy, and the Participant 5 mentioned to have received help by looking at the two course examples.

> *"Applying the Perkin's 7 principles [to the course content] was challenging last week. This week, I was able to understand how to apply the different principles after discussing with participant 6 and participant 7 and looking at how they applied the principles. I then got ideas on how I can apply them to my course."* (Participant 5 – week 4 interview)

Theme 4 – Shift in Teaching Philosophy from Teacher-Centric to Student-Centric Approach

In this theme, I present one of the immediately observed outcomes of the 6-week professional development program as the participants started to emphasize on the need to follow a student-centered approach in their instruction. I talk about multiple instances where the participants through their actions and beliefs were observed to consider the students' learning as the primary motivator for any changes to be made to their course. During the 6-week program, they started to critique and identify issues from their prior teaching experience by taking students' perspectives into consideration. Participants, as a result, reported to slowly shift their philosophy from a teacher-centric to student-centric approach. They interacted with their students to take feedback on their final design projects and ensure that the technology tools being integrated are user-friendly. While identifying the technology tools, the participants also included concept maps as a technology tool that would help them present to the students the overview of the course. They believed that the use of concept maps would aid the students in understanding how the different course topics are connected to the enduring outcomes of the course. Figure 16 describes the thematic development of theme 4 from the different codes and categories.

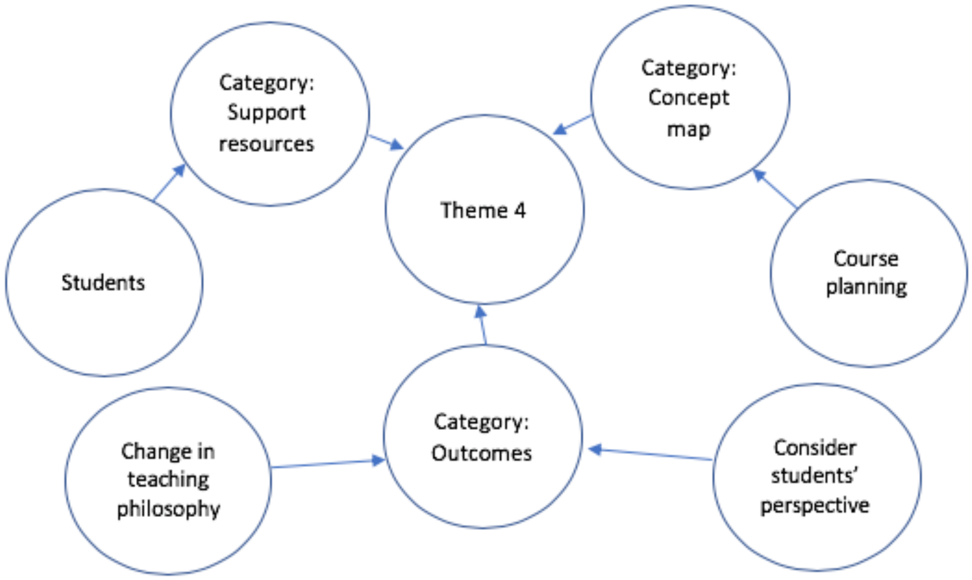

Figure 16 – Thematic mapping of emphasis on student-centered learning

A visible change was observed in the teaching philosophy of the participants during and at the end of the professional development. Participants reflected on their prior teaching experience to become aware of how their instruction was more teacher-centric in the past.

> *"Right now, the difference I feel is, I never thought that my course could have some misconceptions and difficult concepts. I just used to teach all the content in the same way. I never reflected on how students are learning in the course"* (Participant 3 – week 2 interview).

> *"as an instructor, we are used to teaching the course based on the content prescribed by the university. The focus was always on teaching the content on time and never on making sure students achieve the desired learning outcomes"* (Participant 4 – week 6 interview).

> *"Earlier, the motto was to look at the content only from the instructor's perspective. In previous faculty development workshops, we did not get the opportunities to look at the course content from the students' perspective".* (Participant 7 – week 6 interview)

Participant 5 in her week 6 interview revealed how she previously prepared the course file that contained all necessary information about the course without the intention to ensure it was helpful to the students.

> *"when I developed the course file, it was more like "this is the content I want students to learn, so I will include it in the course file", and I thought my job is done. Now I am more aware of what content I am including and making sure it is helpful for students".* (Participant 5)

Most of the participants were observed to shift the focus of their instruction from a teacher-centric to a student-centric approach. Participant 5 in her final reflection talked about how she now believed that students have a bigger role than just being a passive learner in the classroom. She mentioned that learning in a classroom can by a two-way process and how she can learn more about students' experience in the course by interacting with them.

> *"Everyone in the classroom contributes as a student, teacher, and thinker. I learn from students as much as they learn from me and I believe that we never stop learning. Good instructor should follow learner centric approaches and motivate students for more value-added education. We should constantly engage with the students to take feedback that will help us keep improving as an instructor".* (Participant 5 – final reflection)

Participants believed that the instructors now have an additional responsibility to transfer students' learning to their long-term memory and ensure the retention of knowledge.

> *"As a teacher, we think students should read and remember all the topics in the course with a hope that those topics will be used when they work in the industry. By using the cognitive theory of learning, I realized the responsibility is on the instructor to transfer the learning to long term memory".* (Participant 2 – week 6 interview)

> *"It was great to look at the various encoding and retrieval strategies, and cognitive theory of learning i.e., converting working memory to long term memory. It is our job as an instructor to transfer the learning of students to their long term memory."* (Participant 4 – week 2 interview)

Participants after looking at the backward design process that was introduced during week 1 of the professional development reported that they were until now assessing the students based on what they taught instead of measuring what they learnt.

> *"We have been thinking about the assessment to measure what we teach and not using assessment to measure if students have achieved the learning outcomes of the course. I realized this is needed from understanding the backward design process."* (Participant 4 – week 2 interview)

Participants in their final reflection started to take students' perspective about the course into consideration while planning for a lecture. They mentioned the importance of an instructor to develop pedagogical content knowledge in order to be a good instructor. This was observed to be another instance where they started to re-organize their teaching philosophy to be more student-centric.

> *"I realized that by just knowing the content of the course, we will not be able to efficiently teach the course. The instructor should have an understanding of how the course should be taught and other aspects of the course that are important for effective instruction."* (Participant 5 – final reflection)

> *"We are teachers and teaching should be our main goal. To be a good teacher, I need to have a good understanding of how to teach a particular course based on the needs and background of the learners."* (Participant 6 – final reflection)

Another evidence of the change in teaching philosophy was visible as the participants started to interact more with their students during the class. Participant 1, who was teaching her first course said,

> *"During my first one month of teaching, I used to go to the class and never interact with the students. I would start teaching right away... As I am attending this program, I have started to interact with the students to take feedback and identify the concepts that they are finding difficult to learn. This knowledge would help me to adapt my instruction accordingly and help students."* (week 2 interview)

Other participants reiterated the same as they started to interact more with students to take feedback and keep improving the course.

> *"I realized it is important to take the learners into consideration. I am constantly trying to take feedback from them, identify concepts which might be perceived difficult by the students. This knowledge would help me adapt my instruction accordingly in order to maximize the learning of the students."* (Participant 3 – week 6 interview)

> *"My prior teaching, I never asked the students about the challenges they are facing. Now that I interacted with the students, I know that there are certain concepts which are difficult for the students to learn."* (Participant 5 – week 2 interview)

The participants mentioned to take feedback from their students while working on the final design project. Similar to a true design process, few of the participants considered the students as the end users of their final project and regularly interacted with them to take feedback. Participants wanted to ensure their final projects were user-friendly and asked students in their course to use the website and provide suggestions for improvement:

> *"While mapping pedagogy, content, and technology, I feel like I mapped them but I'm not sure if what I am doing is going to be most beneficial to students. So I think I can only*

evaluate my final project after implementing it in my course and taking students feedback." (Participant 2 – week 6 interview)

"It is important that the tools we are using and the resources we are providing students should be user friendly. Students should not be worried about being able to access and use the resources. We need to develop resources by always taking students into consideration." (Participant 2 – final reflection)

"When I developed the course website, I did it by myself in the start. To make it student friendly, I included students in the development process and introduced them to the website. When students starting using it by viewing the content and posting assignments, they provided me some suggestions on other tools that can be incorporated on the website" (Participant 4 – week 6 interview).

Participant 7 continued to interact with the students as he aimed to regularly improvise his course website every year:

"*They gave some suggestions on how I can improve the blog website and what additional features would be helpful to them. By talking to my students, I plan to keep improving the website every year."* (week 6 interview)

After the completion of the professional development program, one of the participants in his final reflection mentioned the determination to think about different ways to help students in the course:

"I believe this is just a start and I will need to constantly work to evaluate and identify better tools that might be helpful to my students." (Participant 2)

Participant 5 mentioned that she is motivated to develop TPACK for all the other courses she will teach in the future:

> *"The interesting part of this faculty development program is how to teach any concept in a particular way. We could apply a pedagogy technique and we could use a specific technology tool… Now I want to apply my learning to all future courses I will be teaching, so that a plan can be developed from the start of the course."* (final reflection)

Similarly, participant 6 wanted to look for advanced technology tools for his course and explore others approaches that would help him bridge the gaps between industry-academia:

> *"I kept thinking about what else I could do apart from the course website to support students' learning. I wanted to design something else as a lot of industries are using automation in their process right now. I wanted to show my students a device through which I could teach them the process of automation. Basically, trying to teach them topics that might be relevant to the industry. I want to continue thinking on how I can use not only education technology but also other technology such as robotics to teach my course."* (week 6 interview)

This is particularly important to the development of TPACK, as the instructors need to continuously improve their technological knowledge and stay up to date with the latest advances in educational technology. Students being more aware of the latest technological trends could be a valuable resource to develop the technological knowledge of the instructors.

Another instance of the participants shift to a student-centric approach was observed when they reported to use concept maps to present the overview of their courses to the students. After going through the exercise of developing multiple versions of concept maps, the participants during the week 6 interviews reported that the experience of developing the concept map could help them in the preparation of course activities and materials prior to the start of the semester. I made a note during my observations that the motivation for the use of concept map aroused after the participants realized the value of structural representation of the course content. Participant 1 reiterated the same as talked about how she previously planned classroom activities when necessary instead of doing it prior to the start of the course:

"Earlier I used different pedagogies based on when I needed them on a specific day in the class. But now by using the concept map, I introduced the course and listed the enduring outcomes, the pedagogy and technology, and then got a big picture of the whole course... By seeing the concept map I drew, it will help me to plan for the different learning resources in advance and have a better understanding on how to best structure and teach the course" (Participant 6 – week 6 interview).

The participants reported to wanting to use the concept map to provide the students an overview of the course. They could use the concept map to present the students with the enduring outcomes of the course, show how the enduring outcomes are related to the course content, and how the various classroom activities or learning resources could help them in achieving the enduring outcomes.

"if I had developed the concept map prior to teaching the course, I could have explained to the students how the different topics are interlinked to each other and they would have better understanding of the overall course and its content." (Participant 1 – week 6 interview)

"once I started, I was able to just think aloud and mention about what are the enduring outcomes, the difficult concepts and the misconceptions. If the topics were interrelated, we can mention to the students that understanding of this topic will help you in the understanding the next topic. So developing the content part of the concept map, I realized I could present the overview of the course in a different way." (Participant 2 – week 6 interview)

"While developing the concept map, I realized that we can provide students an overview of the course by using the concept map. We can explain them the course content, and what the pedagogy and technology tools we will be using for the course. We can mention where we will be using the tools and why we are using them for that specific content or topic." (Participant 4 – week 4 interview)

> *"After completing the concept map, I have shared it with my students and they were very excited to see it. I also took feedback from them and students mentioned that the concept map provided them a very good overview of the course"* (Participant 7 – week 6 interview).

Previously, the participants provided the students with a course file that included the course outcomes, class schedule, list of textbooks and references, and other necessary information. The participants now recognized the limitations of that approach in terms of organization and time management:

> *"Before, we were developing course files which is difficult to show in detail to the students. But with the concept map, we can quickly give students an overview of the whole course, the activities that will be conducted and the technology tools that will be used. With the concept map, we can save time"* (Participant 4 – week 4 interview).

Participant 3 reiterated the same and emphasized the added value of using concept mapping software tools, as they allow users to embed some of the learning resources in the concept map:

> *"I realized that by using concept map tools, I can present the course outline to the students in a much efficient way. Also, the tool Mindmeister allows you to attach files to each node and that would provide students a more structured way to access the content."* (week 4 interview)

Participants responses to use concept maps to present overview of their course highlight their increased emphasis on student-centered learning as started evaluating different ways of helping students learn and succeed in the course. The quotes presented in this theme highlight multiple instances where the participants started to think about the students while preparing for the course materials, planning for classroom activities, and identifying technology tools for the course. Participants were motivated after the end of the 6-week program to continue being more student-centered in their approach for the current and future courses they will teach.

Summary of Themes

The participants in this study described the process of developing the various constructs of TPACK and how they utilized TPACK during the 6-week professional development program. Four themes emerged from the thematic analysis of participants' interviews, reflection journals, and the final reflections.

- Theme 1: Critical reflection and metacognition necessary skills for the development of TPACK.
  - Sub-theme 1.1 – PCK, TCK, and TPK constructed by engaging in critical reflection and forming mental models using the TPACK sub-domains.
  - Sub-theme 1.2 –TPACK developed by combining the knowledge of intersecting sub-domains to address learning needs of students and current limitations of instructors.
- Theme 2: Low technology self-efficacy hindered the usage of technology tools.
- Theme 3: Community of Practice (CoP) members with varied prior teaching experience helped in the development of tacit knowledge.
  - Sub-theme 3.1 - Prior teaching experience used as an internal support mechanism while engaging in reflection.
  - Sub-theme 3.2 – Community of Practice helped in generation of ideas, clarifying misconceptions, providing feedback, and enabled the exchange of knowledge.
- Theme 4: Shift in teaching philosophy from teacher-centric to student-centric approach.

CHAPTER 5. DISCUSSION

5.1 Introduction

In this chapter, I analyze and answer each of the research questions by discussing the findings that emerged from the different themes and sub-themes presented in the previous section. I also present the implications of this study by providing individual targeted recommendations to faculty developers and higher education institutions. At the end, I talk about the limitations and conclude the study. The arguments presented in the discussion are grounded in prior literature when necessary.

5.2 Development and use of the various constructs of TPACK during the professional development experience

In this section, I discuss research question 1 by considering themes 1 and 4. In these themes, the participants talked about the process they followed while developing TPACK and how they applied the knowledge of the intersecting sub-domains (pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge) and TPACK to re-design a course of their choice. Theme 4 highlights how the development of TPACK has increased the participants' emphasis on student-centered learning at the end of the 6-week professional development program.

- Theme 1: Critical reflection and metacognition necessary skills for the development of TPACK.
    - Sub-theme 1.1 – PCK, TCK, and TPK constructed by engaging in critical reflection and forming mental models using the TPACK sub-domains.
    - Sub-theme 1.2 –TPACK developed by combining the knowledge of intersecting sub-domains to address learning needs of students and current limitations of instructors.
- Theme 4: Shift in teaching philosophy from teacher-centric to student-centric approach.

5.2.1 3 Phases of development of TPACK

The participants in this study were observed to develop TPACK in three phases. In the first phase, they developed knowledge of the basic-subdomains of TPACK i.e., content knowledge, pedagogical knowledge, and technological knowledge. The participants in the second phase formed mental models to understand the interrelation between the TPACK sub-domains and constructed pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge. For example, the participants constructed technological content knowledge by forming a mental model of how a technological tool could be used to teach and represent a specific course content. In the third and final phase, participants developed technological pedagogical content knowledge (TPACK) by combining the knowledge of the intersecting sub-domains they built in phase two. The three phases as indicated in Figure 17 was a result of the sequence observed in the participants' responses on how they developed TPACK during the different stages of the data collection process. The timeline indicated in the subsequent sections for the three phases was a result of the structure of the professional development program, as each week of the program was designed to help the participants develop the knowledge of different constructs of TPACK. However, the hierarchy in terms of how the knowledge in each phase was constructed using the knowledge gained from the previous phase as indicated by the themes that emerged from the data analysis process.

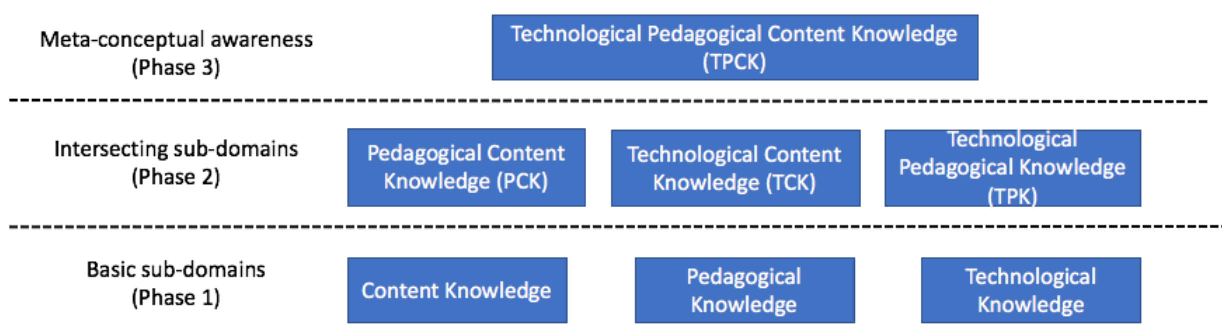

Figure 17 – Three phases of development of TPACK

Phase 1

In the first phase (weeks 1 - 3), participants constructed knowledge of the basic subdomains of TPACK (content knowledge, pedagogical knowledge, and technological knowledge) by using their prior knowledge and the content presented to them during the professional development sessions. While most of the participants attended the 6-week program with high content knowledge, I introduced the participants with multiple pedagogical frameworks that could be applied to transform their courses based on the learning needs of the students. Participants were also presented with a range of technological tools that were widely used for educational purposes. This built a basic awareness among the participants of the different technological tools that were available, and they were asked to learn how to use them depending on the requirements for their respective courses. In this phase, all the participants built generic pedagogical and technological knowledge that could be applied to any course.

Phase 2

In the second phase (weeks 2 – 6), participants started to transform their knowledge of the basic sub-domains into the intersecting TPACK sub-domains (pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge) by forming mental models. A mental model is a representation that an individual forms in their mind to psychologically interpret the world and understand the relationship between things (Johnson-Laird, 1980). Participants in this phase were challenged to construct knowledge of how a certain pedagogical or technological tool could help them address a learning need of the students and help them succeed in the course. Generic knowledge is used as a frame of reference to guide the formation of mental models (Brewer, 1987), and the participants situated the basic knowledge of the TPACK sub-domains in their respective courses to develop knowledge of the intersecting sub-domains.

Pedagogical content knowledge

In week 2, participants started to construct pedagogical content knowledge as they were encouraged to think about what makes certain topics difficult for students to learn and how they could use different pedagogical tools to help students achieve the enduring outcomes of the course. Participants analyzed their course content from the students' perspective by forming mental models of instances when the students had difficulty or challenges while learning in previous offering of the course. Participants then examined the relationship between content and pedagogical knowledge by looking at how they could use certain pedagogical tools to help address the challenges encountered by students. For example, participants constructed mental models of why and how Perkin's 7 principles of making learning whole (Perkins, 2010) could be applied to their respective course (a framework introduced to participants in week 2) and designed appropriate learning activities that could be implemented in the classroom. Participant 1 mentioned to include authentic learning activities that would make the course content more meaningful to the students and improve their motivation in the classroom. The authentic learning activities were also aimed to improve the retention of knowledge among students after the completion of the course. Participant 1 included the authentic learning activities after applying one of Perkin's 7 principles (make the game worth playing) to her course content and as a result developed pedagogical content knowledge. Similar to participant 1, participant 6 applied the principle of "working on the hard parts" by including a few laboratory sessions as part of the course schedule. He identified that it was difficult for him to teach to the students the internal working of an electrical machine inside the classroom. He relocated few of the classroom sessions to the laboratory where students can engage in apprenticeship and develop an understanding of how the electrical machines functioned.

Technological content knowledge

Participants developed technological content knowledge as they started to construct mental models of how they could use their technological knowledge to address some of the content related issues which they observed the students to encounter previously. Participant 5 identified some challenges that students encountered while visualizing a few topics in her course "Electromagnetic Waves" and looked for pre-existing online videos that would help students to visualize the course content. Participant 3 encountered similar challenges in her freshmen "Engineering Graphics" course that required students to utilize their spatial thinking skills to solve problems and succeed in the course. She identified a repository of online videos that she planned to use to solve problems in the classroom and as a result improve the spatial thinking skills of the students. Participant 2 was teaching a course where some of the topics required repetitive learning i.e., content which she expected students to remember after the end of the course. She explored some of the audio tools that I introduced to the participants in week 3 and created audio files that students can continuously access and utilize to meet the enduring outcomes of the course. Participant 1 who wanted to implement authentic learning activities in her course looked for movie making technology tools that she could use to represent the real-life application of some of the topics.

Technological pedagogical knowledge

Participants developed technological pedagogical knowledge by constructing mental models and identifying technology tools that could be used to implement some of the pedagogical activities they planned for the course in week 2. Both participants 5 and 7 wanted to implement a flipped classroom pedagogy for few of the class sessions. They identified different technology tools that they could use to share the classroom content with students prior to the start of the class. Participant 5 wanted to use the flipped classroom approach specifically to clarify some of the misconception's students developed in her course. Participant 6, who wanted to encourage student-student interaction prior to the start of the class, identified a discussion forum that he could use to post discussion questions. Participant 4 realized that students are currently relying only on the content available in the text book and identified a social bookmarking tool that he could use to provide students with additional content. Most of the participants who wanted to provide facilitate student-student and student-instructor interactions outside of the classroom sessions reported to look for some kind of asynchronous discussion forum that would allow and support the interaction.

Phase 3 - Technological Pedagogical Content Knowledge

During the third phase of developing TPACK, the participants started to combine the knowledge of the intersecting sub-domains as they completed their final design project. Krauskopf et al. described TPACK as a meta-conceptual awareness of the demands as an instructor, their knowledge of the TPACK constructs, and the context of operation (Krauskopf et al., 2015).

Participants in this phase used their knowledge of the intersecting TPACK sub-domains (pedagogical content knowledge, technological content knowledge and technological pedagogical knowledge) to address some of the limitations they experienced while teaching in the traditional lecture-based format. Most of the participants developed technology-mediated support resources as a part of their final design project to address certain unique challenges that students faced in their respective courses. Participant 2, for example, created a course blog for her final design project where she shared the links to many online videos that would help students visualize and understand the course content. She developed the blog after acknowledging the limitations of the current mode of instruction where she could not take the students on regular industrial visits to depict the working of mobile communication systems.

Another limitation that was recognized by most of the participants were the limited classroom sessions that were available to them during the semester. Acknowledging the challenges with the limited classroom hours, most of the participants developed course websites that would provide students access to learning resources outside the classroom. Participant 4, for example, identified course content that students could learn by themselves and used the course website to share the content with the students prior to the start of the class. He wanted students to learn the theoretical aspects of the content before coming to class, so that he can spend the classroom time on solving examples and help students apply the knowledge. Participant 7 wanted to use his course website to provide students access to additional quizzes that they could solve outside of the class. The participants also intended their course websites to support student-student and student-instructor interaction outside of the classroom (another challenge of the limited classroom hours). Participant 1, who was teaching the course for the first time, wanted to use a discussion forum on the website to answer student questions that she was unable to answer immediately in the classroom. However, it is important to note that the completion of the final design project was time consuming and few of the participants were unable complete their projects at the end of week 6. Participants 1 and 2 needed two additional weeks to complete their course website and blog respectively. When I asked the participants in week 6 about the reasons for the delay, both of them admitted the lack of prior experience with teaching the course and low technology-self efficacy to be the key reasons for needing the additional two weeks to complete the final design project. The participants required additional support to critically reflect on students' experiences in the course and to successfully integrate technology tools into their courses. Both of these are discussed in more detail in the subsequent sections.

5.2.2 Reimagining course content representation and pedagogy as a result of the affordances of technology

Participants reported while working on their final design project that the implementation of technology tools made them rethink the organization and representation of their course content. The participants believed that the affordances offered by various technology tools made them restructure their course content in limited classroom lecture hours available to them. One of the challenges that the participants face as an instructor is time management. Participants while developing pedagogical content knowledge were asked to establish the curricular priorities for their course. The curricular priorities framework requires instructors to organize their course content into three categories: enduring understanding, important to know, and worth being familiar with (Wiggins & McTighe, 2005). Participants could now use the online tools or mobile technology to provide students access to the course content they categorized as worth being familiar with. This would allow them to spend more time on topics that are required for the enduring understanding of the course. The newer technology tools inspired the participants to rethink and evaluate how the course content could be presented using varied representations. Participants while developing technological content knowledge identified technology tools that would allow them to help students visualize the course content. This is particularly helpful for many engineering courses that require high levels of spatial visualization skills for conceptual understanding. Three of the seven participants were implementing their final design project in courses that required students to visualize the concepts taught in the classroom. Engineering faculty in the next few years can also explore the utilization of advanced tools such as non-immersive and immersive virtual reality (VR) technologies that would aid students in the understanding on complex concepts (Pantelidis, 2010).

Few of the participants after realizing the affordances of technology tools implemented new pedagogical activities that would help address some of the misconception's students encountered in the course. For example, participants 5 and 7 planned to implement a flipped classroom approach for a few classroom sessions by providing students access to the learning resources using technology tools prior to the start of the class. By using technology tools, participants came up with strategies to regulate students' learning outside of the classroom. Most of them transformed their courses to a blended format where students could have asynchronous access to the course content. Using advanced technology tools, engineering faculty could also implement technology-based pedagogical activities such as computer-aided design, data analysis, experimental simulations, and mathematical modeling (Figg & Jaipal-Jamani, 2017). The affordances offered by technology tools could therefore prompt engineering faculty to reimagine how they could represent their course content and explore different opportunities to implement innovative pedagogical practices.

5.2.3 Increased emphasis on student-centered learning at the end of the 6-week professional development program

One of the immediate impacts that was observed among the participants during and after the 6-week professional development program was an increased emphasis on student-centered learning. Theme 4 presented in the last chapter highlighted the multiple instances when the participants were seen to report a shift in their teaching philosophy from a teacher-centric to student-centric approach. During the 6-week program, participants started to center all their discussions and efforts by taking the students into consideration. While constructing the mental models, participants were seen to critically reflect on their prior experience with teaching the course and identify issues that students have encountered. Many of the participants recognized and reported the misalignment between the content they were teaching and the pedagogic activities they implemented previously. Participants mentioned to use the traditional teaching approach (where students are passive learners in the classroom) without putting any efforts to adapt the pedagogy based on the course content. Participants while forming the mental models acknowledged some of the challenges that students might have faced while representing the course content and identified technology tools that could be used help students visualize the course content.

Responses from participants' week 6 interviews and final reflection revealed a significant shift from a teacher-centric approach in past to a more student-centric approach as a result of the development of TPACK. Many of the participants indicated instances when they taught the course content without the intent to help students achieve the desired course outcomes. Participants while identifying the difficult concepts and misconceptions for the course reported to have started to take students' perspectives into consideration. Some of them reflected on how students learnt the course in the past and interacted with students who completed the course to identify the difficult concepts and misconceptions. Participants then planned appropriate learning activities that were aimed to help students overcome the challenges.

Participants as a result of the 6-week program mentioned to have started a two-way interaction with students in the classroom, which is a significant shift from the passive one-way teaching they followed before. Participant 5 began interacting with students to obtain regular feedback about the course and she believed the interaction with students would help improve her teaching skills. Participants 2 and 4 realized that the instructors have additional responsibilities to ensure that the information presented in the classroom is transferred to students' long-term memory. They later included necessary learning activities while re-designing their course to ensure the effective knowledge retention of the students.

While working on the final design project, the participants had to often think about how the integration of technology would help the students learn in their course. Most of the technology tools that were identified and implemented were targeted to support students' learning outside of the classroom. The participants developed course blogs or websites that would provide students with access to learning resources and enable student-student and student-instructor interactions outside of the classroom. Few of the participants also reported to have shown the final design project to the students to take their feedback. This was done with an intent to make sure the technology tools they were integrated would be perceived to be helpful by the students. Students were able to provide recommendations on how the technology-mediated support could be made more user friendly.

The last instance that revealed the change in the teaching philosophy was the increased emphasis on introducing students to the enduring outcomes of the course. Prior to the start of the 6-week program, participants introduced the course content by providing the list of topics that they would teach throughout the semester. Participants after the 6-week program started to present the enduring outcomes of the course to the students and help them understand how the different topics were interrelated to the enduring outcomes. This was aimed to provide students with a structural representation of the course content. After developing the concept maps for their respective final design projects, participants mentioned to use the concept maps to show students the overview of the course. Participants believed they could use the concept maps to provide students with information on how the enduring outcomes are aligned to the course content and what pedagogy and technology tools they would use to teach the course. Even after the end of the 6-week professional program, participants in their final reflection reported the desire to keep updating their course with newer technology tools and develop TPACK for the other courses they would teach in the future. The intent to continue updating technology tools is aligned with the TPACKing framework that requires instructors to constantly reflect on their teaching experience and explore the latest technology tools available for educational purpose (Olofson et al., 2016).

This significant change in the teaching philosophy statements of the participants could be attributed to the development of TPACK, as the framework and its various constructs must always be situated in a specific context and take the learners into account (Charoula Angeli & Valanides, 2009). The participants while constructing mental models had to think about how the interrelations between content, pedagogy, and technology would help students achieve the learning outcomes of the course. When the participants developed TPACK, they needed to understand how the combination of the intersecting TPACK sub-domains would address the learning needs of the students. The participants in the phase two and three of developing TPACK were therefore required to regularly take the students' experiences into consideration. As shown in Figure 18, the participants in phases 2 and 3 had to construct PCK, TCK, TPK, and TPACK by taking the learners into consideration. An instructor would therefore be unable to truly integrate technology tools (and develop TPACK) without taking the learners into consideration. The TPACK framework, as a result, compels the instructors to constantly think about how the integration of technology tools would assist students in their learning process.

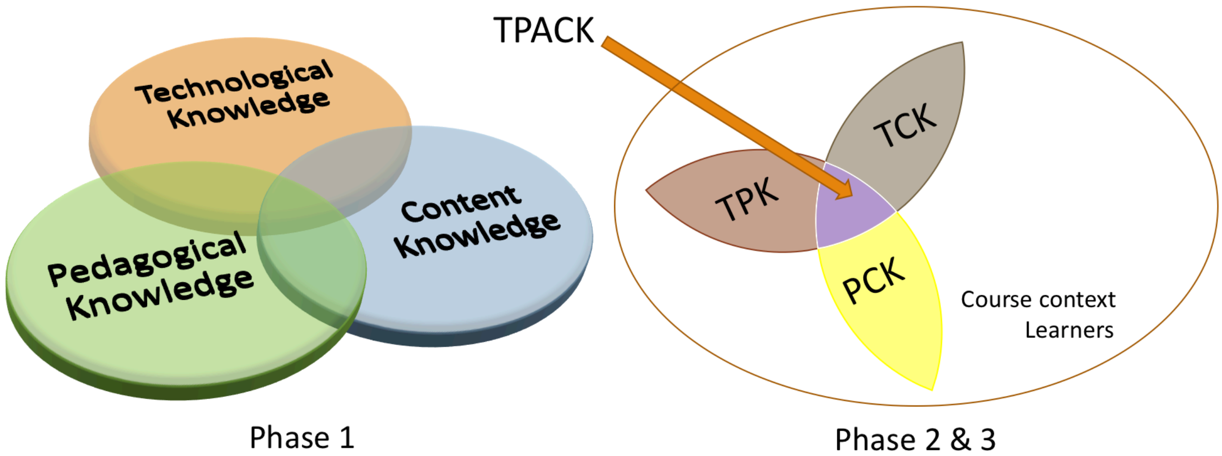

Figure 18 – PCK, TCK, TPK, and TPACK constructed by taking learners into consideration

5.3 Major Challenges Encountered by the Faculty during the 6-week Professional Development Program

In this section, I discuss the challenges that participants reported to encounter during the 6-week program. Themes 1 and 2 identified three challenges that the participants experienced during the different weeks of the professional development program. Participants faced difficulty while constructing mental models and developing pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge. Participants when completing the final design project had trouble while identifying and integrating appropriate technology tools into their courses. I observed that the participants during the professional development sessions were hesitant to use the concept planning tools available online and utilized the tools only after I insisted.

- Theme 1: Critical reflection and metacognition necessary skills for the development of TPACK.
    - Sub-theme 1.1 – PCK, TCK, and TPK constructed by engaging in critical reflection and forming mental models using the TPACK sub-domains.
- Theme 2: Low technology self-efficacy hindered the usage of technology tools.

5.3.1 Critical reflection

All of the participants reported they faced challenges while constructing mental models using the basic sub-domains of TPACK i.e., content knowledge, pedagogical knowledge, and technological knowledge. Mental models are considered to be cognitive structures that are constructed through deeper understanding of a particular situation (Brewer, 1987). To construct a mental model for a specific situation, individuals should be able to quickly access the particular situation-related information (Schnotz & Wagner, 2018). Participants while constructing mental models were required apply the knowledge of pedagogy and technology to address a complex task of teaching the subject and helping students achieve the intended learning outcomes of the course. For this to happen, the participants had to critically reflect and identify specific issues in their prior offerings of the course. While the participants developed the knowledge of the basic TPACK sub-domains, they were unable to immediately engage in critical thinking and develop an understanding of how the implementation of a certain pedagogic activity or technology tool could support students in their learning process. This made it difficult for the participants to form mental models and represent the interrelations between their content, pedagogical, and technological knowledge. All the participants reported to experience difficulties while constructing mental models to develop pedagogical content knowledge during week 2 of the professional development program. Participants were unable to decide why a pedagogic technique should be adapted based on the course content.

However, participants started to overcome this challenge in the subsequent weeks as they started to develop the concept maps for their respective courses. While developing the concept maps, I encouraged the participants to ask themselves critical questions and mention the reasoning behind using a pedagogic technique and think about how the implementation of the technique would address a specific course-related issue. Participants reported the interaction with the other members of the community of practice helped them to critically reflect and start developing pedagogical content knowledge. It was observed that few of the participants continued to face challenges while developing technological content and technological pedagogical knowledge. Participants reported that the development of pedagogical content knowledge required practice and time.

"Developing the concept map was delayed as it took a lot of time to think and make the connections [between content, pedagogy, and technology]. I wouldn't say concept mapping was difficult but it took a lot of time." (Participant 3)

"We might need more time and support to connect the content and pedagogy. This has been challenging because we have never done this before." (Participant 5)

"The challenge is to identify the optimal choice which could best help my students. Reflecting on what I am learning and applying it to my own teaching practice has been a little challenging and time consuming." (Participant 6)

It is important to note that all of the participants were able to critically reflect after spending a sufficient amount of time to critique the course taught in the previous semesters. This is consistent with prior literature that suggests that an instructor is able to critically reflect on their teaching practice only after self-reflection and deep examination of personal beliefs and assumptions of students' learning process (Larrivee, 2000). Instructors are expected to challenge the status-quo and question their beliefs about their current teaching and learning process. It was therefore challenging for the participants in the initial weeks of the 6-week program, as they had to challenge themselves of their beliefs of following a teacher-centric instruction and form mental models by taking the students' experiences into account. Becoming a critically reflective instructor is therefore considered to be an essential skill to transform one's teaching practice (Thompson & Pascal, 2012). The development of critical reflection skills was also noted to be necessary for instructors to be able to effectively improvise their courses after attending a faculty development program (Behar-Horenstein, Schneider-Mitchell, & Graff, 2009).

5.3.2 Technology self-efficacy

Participants while working on their final design project had challenges while identifying and implementing the appropriate technology tools for their course. Even though the participants were enthusiastic about learning to use technology tools, I noticed that they were initially hesitant to explore how they could integrate and implement the different technology tools introduced to them in the week 3 of the professional development program. When the participants were asked to develop the concept map using the different tools available online, most of them (except Participants 4 and 7) made use of them only after I insisted during the session. While I acknowledge that this is a bias I might have introduced to the study as the facilitator, the participants as described in theme 2 reported to become comfortable with using the tools once they got accustomed to it. All of the participants experienced challenges while identifying and integrating technology tools into their courses. Some of the challenges were attributed to the low technology self-efficacy and technological knowledge to successfully integrate the tools into their courses. Many of the participants encountered different type of trouble shooting errors while completing the final design project. Participants mentioned that most of the technology tools introduced in week 3 were new to them, and they had issues while learning to integrating them into their respective courses. I observed that when Participant 6 presented to the whole group (during week 5) about wanting to use a canvas platform to create a course website, most of the other participants (except Participant 2 and 7) chose the same platform for their final design project. While the Canvas platform provided the participants with all the necessary features they required, they did not explore the other tools available to them. Participant 5 looked at the other tools available for website creation but ended up using the Canvas platform as she did know how to use the tools she explored. The lack of exploring different tools could be attributed to low technology self-efficacy and confidence of the participants to successfully integrate the technology into their courses. Faculty developers might therefore have to be vigilant of how the participants are making use of the technology tools and provide a nudge to the participants with low technology self-efficacy.

Prior work has reported that faculty who demonstrated high self-confidence and had positive attitude towards using technology were more likely to utilize technology for instruction (Holden & Rada, 2011). Four of the participants in this study mentioned to have never owned a laptop and only utilized the PCs made available to them in their respective departments. The Technology Acceptance Model (TAM) developed by David (Davis, Bagozzi, & Warshaw, 1989) has been often used to explain the factors affecting individuals' actual use of technology. As shown in Figure 19, the usage of technology is influenced by an individual's behavioral intention to use technology, perceived usefulness, and perceived ease of using technology.

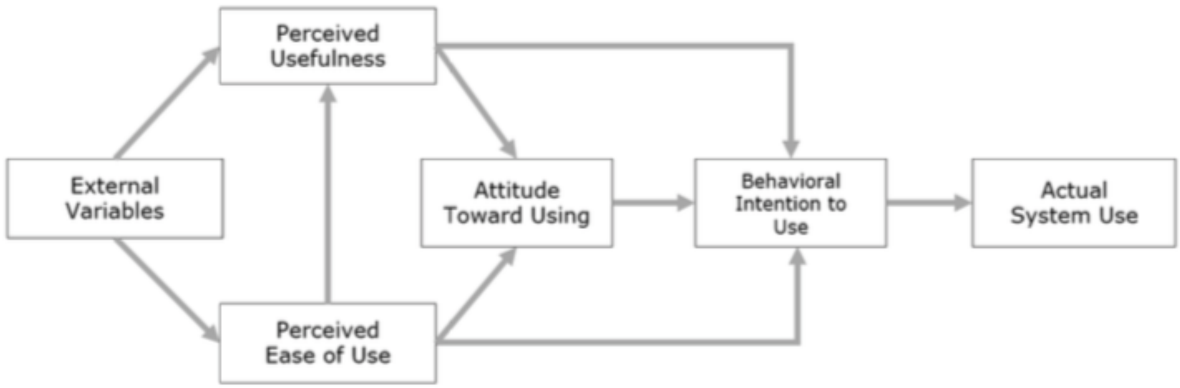

Figure 19 – Technology acceptance model (TAM) (Davis et al., 1989)

While all the participants had the intention to use technology and perceived the usefulness of the tools while working on the final design project, they perceived the use of technology to be challenging. However, the perceived ease of using technology improved after the end of the 6-week program. For example, participant 2 mentioned,

> *"In the start I found using the technology tools to be difficult but at the end it seemed easy. This was a consequence of practice"*.

The same was observed with other participants, who in spite of facing initial challenges were able to successfully integrate technology into their courses and complete the final design project. Participants' attitude towards using technology in courses was observed to now change at the end of the 6-week program as they wanted to continue exploring other tools:

> "*I was excited to explore the different tools, I have now decided that as a teacher I need to keep looking for new tools that can help students to find the course exciting"* (participant 5).

Both these observations are consistent with prior work that reported that TPACK positively and significantly influences an instructor's perceived ease of use and perceived usefulness of technology (Alsofyani, Aris, Eynon, & Majid, 2012; Ju Joo, Park, & Lim, 2018). Horzum and Gungoren studied preservice teachers in technology-based environments and found that the teachers were more likely to perceive the easy usage and usefulness of technology when they learnt how to apply and use TPACK in their classrooms (Horzum & Gungoren, 2012). Instructors who have high levels of TPACK would therefore be more likely to constantly evaluate and redesign their courses with newer technologies, a process referred to as TPACKing (Olofson et al., 2016).

5.4 Major sources of support used by faculty to navigate through the challenges

In this section, I discuss the major sources of support that the participants resorted to during the 6-week professional development program. Participants, as identified in theme 3, utilized the community of practice members and their prior teaching experience as the key resources to overcome the various challenges they encountered while developing TPACK and completing the final design project.

- Sub-theme 3.1 – Prior teaching experience used as an internal support mechanism while engaging in reflection.
- Sub-theme 3.2 – Community of Practice helped in generation of ideas, clarifying misconceptions, providing feedback, and enabled the exchange of knowledge.

5.4.1 Community of Practice (CoP)

A CoP comprises individuals who share a common concern about a topic and are willing to extend their knowledge and expertise by regularly interacting with the other members of the CoP either virtually or in-person (Wenger et al., 2002). Wenger et al. defined a CoP by three characteristics: a *domain* of interest, a set of *practices* that would contribute to the development of knowledge and resources, and a *community* of members who are willing to respect and learn from each other. Before the start of the professional development program, a CoP was established with the participants agreeing to focus on a common domain of interest i.e., integrating technology into their respective course. The 6-week professional development program was organized as one of the first practices of the CoP that would help the members develop TPACK. During the professional development sessions, the participants were provided with multiple opportunities to collaboratively work on specific activities and interact with the other members of the CoP while working on the final design project.

The CoP members were observed to help each other during the generation of ideas, clarifying misconceptions, and providing feedback to each other. Starting from week 4 of the professional development program, participants were asked to start thinking about their final design project. A few of the participants mentioned that the interaction with the CoP members helped them in conceptualizing their final design project. Both Participants 1 and 2 who have low prior teaching experience reported to receive help from the other CoP members that helped them to generate ideas for their final design project. Participants with higher prior teaching experience also mutually benefited from the interaction with their peers as they got feedback on the design choices for the final project. Participants utilized their peers to receive constructive feedback as the CoP members helped them ask critical questions while engaging in discussions and group activities. The interaction among the CoP members was observed to also help the participants overcome few of the challenges they faced while constructing mental models and developing knowledge of the intersecting TPACK sub-domains. Participants 1, 2, 4, and 5 reported to have gotten support from Participants 6 and 7 while developing concept maps for their courses.

The diversity among the CoP members in terms of the discipline of engineering helped the participants understand how TPACK and its utilization would vary depending on the course. Participants believed that the CoP members enabled exchange of knowledge of the basic sub-domains of TPACK. During this time, the participants clarified the misconceptions that their peers have developed especially with respect to their pedagogical and technological knowledge. The participants perceive a lot of value in the CoP member interactions especially while working on the final design project. During week 3-6, participants were often asked to present and share their progress towards the final design project. The presentations done by the CoP members helped the other participants as they provided feedback on their final design projects. During week 5 and 6, the participants were observed to extend their interaction with the other CoP members outside of the professional development sessions. They met with the other participants to help them identify the technology tools that they could implement in their final design projects and address any trouble shooting errors they encountered while integrating the technology tools.

To summarize, the participants received helped from the CoP members during the construction of mental models, while conceptualizing the final project, and while addressing the technological issues. It is important to note that the conceptualization of the final project required the participants to possess a metacognitive awareness of the context of operation, the demands of their instruction, and the knowledge of the intersecting TPACK sub-domains. For the constructing of mental models, the participants needed to exhibit critical thinking skills and the ability to engage in reflective practice. The successful completion of the final design project required the participants to have high technology self-efficacy and technological knowledge. Most of the skills mentioned above i.e., metacognition, critical thinking, and reflective thinking could be considered as tacit knowledge that cannot be easily taught to the participants (Eraut, 2000; Golding, 2011; Kinsella, 2010). Few of the participants as discussed in the previous sections encountered challenges due to the lack of this tacit knowledge and later developed these skills during the 6-week program. It is therefore necessary to highlight that the formation of CoP helped the participants utilized the CoP members to navigate through all of these key challenges (including low-technology self-efficacy) and successfully complete their final design project.

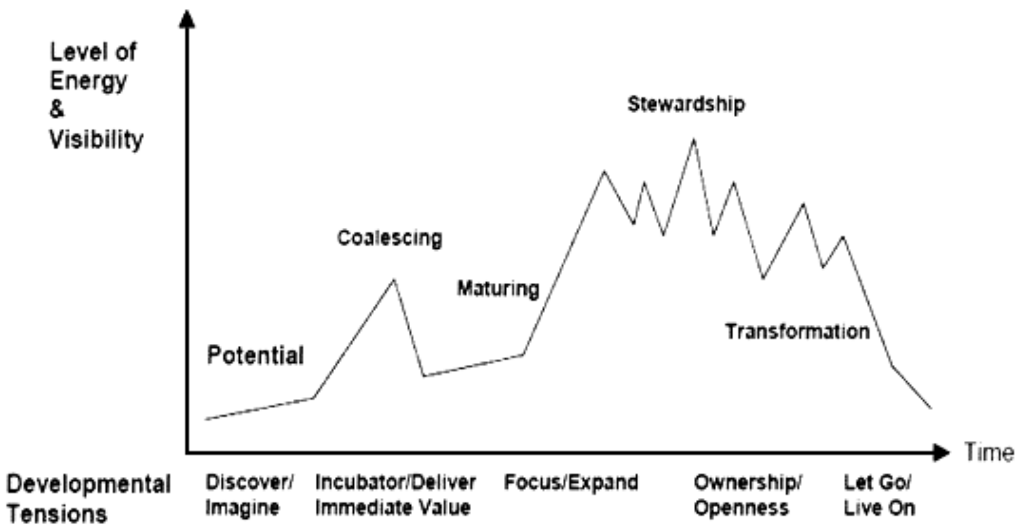

Figure 20 – The different stages of a CoP (Wenger et al., 2002)

The CoP members, after the end of 6-week professional development program, have included additional practices that would help them to continue developing TPACK. Figure 20 shows a framework suggested by Wenger et al. that describes the lifecycle of a CoP. During the 6-week program, the CoP was still in the potential stage where the community gets established as a small network and has a potential to grow and form more connections. After the 6-week program, the

CoP started evolving to the coalescing phase as more members showed willingness to join the community. The CoP participants later organized a 1-day workshop by themselves to share their experiences of developing TPACK as part of the 6-week professional development. The 1-day workshop was organized to motivate and generate interest among other faculty in the institution to join the community. The initial CoP members now planned to conduct additional professional development programs where they could share their knowledge and help the new members learn to integrate technology into their courses. The organization of new the activities by the CoP members indicate the strong sense of community that was fostered among the participants. Faculty developers have recommended the development of CoP as way to ensure the sustainability of faculty development initiatives (Smith, Hurst, & Murakami, 2016). The CoP framework could therefore be used to develop sustainable internal expertise, and the core members of the CoP could later continue to facilitate faculty development efforts in the institution (Stark & Smith, 2016).

5.4.2 Prior teaching experience

Helping participants reflect on their teaching practice has been considered as a crucial aspect of faculty development programs (Hubball, Collins, & Pratt, 2005). To engage in reflective practice, instructors should be able to self-reflect on a particular situation to understand the consequences of classroom practices on students (Larrivee, 2000). Participants during the 6-week program were asked to often critically reflect on prior offerings of their course and identify some of challenges that students might have encountered. The critical reflection was essential skill the participants needed while forming mental models and developing pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge. Participants were observed to resort to their prior teaching experience while they engaged in reflection and wanted to take the students perspectives into consideration. While identifying the difficult concepts and misconceptions for their course, they used their prior teaching experience to think about how students learnt and understood specific topics in their course before.

Participants with limited or no prior experience reported to struggle while engaging in reflective practice. For example, participants 1 and 2 (who were teaching the course for the first time) could only reflect on the time when they learnt the similar course as a student and had no way to reflect on students' experience from the perspective of an instructor. Both participants 1 and 2 had to interact with the other instructors in the institution who taught the course in the past and use their reflection as a frame of reference. Participants 1 and 2 as a result mentioned that instructors should teach a specific course at least once to understand how to effectively integrate technology tools into their courses. It was therefore challenging for them to develop knowledge of the intersecting sub-domains of TPACK and complete developing the concept map.

Participants who engaged in reflective practice were able to quickly start making the connections among the three TPACK sub-domains as compared to the participants who had limited or no prior teaching experience. Participants 6 and 7 were much quicker at developing and reiterating their concept map as compared to the others. While most of the participants completed the development of their concept maps by week 4, Participants 1 and 2 took longer time and were only able to complete the concept maps by the end of week 5. The longer time taken for developing the concept map later impacted on the completion of their final design project. Both Participants 1 and 2 required additional time to finalize the ideas for their project and took an additional two weeks after 6-week professional development program to submit and present their final design project. The prior teaching experience, as a result, helped the participants to be more efficient on accomplishing the tasks provided to them during the professional development sessions and while completing their final design project.

It was observed that the participants who had experience using technology tools in their prior teaching experience had higher technology self-efficacy as compared to the others. Both Participants 4 and 7, who taught courses in computer science and engineering department, were more open to exploring and utilizing the technology tools that were introduced to them during week 3 of the professional development program. This was a result of their higher usage of computer-based technologies while teaching courses to the students, which increased their perceived ease of using technology tools. The other participants reported to often seek help from Participants 4, 6, and 7 while identifying the technology tools for their respective courses and for solving the trouble shooting errors that they encountered while integrating the identified tools. The diversity among the participants in terms of their prior teaching experience and discipline of engineering therefore promoted meaningful exchange of knowledge.

5.4.3 Concept mapping tools

As all of the participants reported to face challenges while constructing the mental models during week 2 of the professional development program, I introduced to them the process of concept mapping. Concept map is a process of graphically representing the content and is widely used for course planning and evaluation (Kane & Trochim, 2007). Concept mapping helps instructors to think and visually observe the inter-relationships between different elements of the course (Streveler, Smith, & Pilotte, 2012). Participants reported that the concept mapping process helped them visually represent the interrelations between their knowledge of content, pedagogy, and technology. The concept mapping tools required the participants to specify and provide the rationale of why they planned to implement a specific pedagogic technique or technology tools to teach a particular course concept. The concept mapping process therefore helped the participants while constructing the knowledge of the three intersecting TPACK sub-domains, as they could now visualize, situate, and understand the interrelations between content, pedagogy, and technology with respect to their courses. The concept maps later helped few of the participants conceptualize their final design project as the concept map served as a design porotype of how that planned to integrated technology tools into their respective courses.

5.5 Implications of the Findings

In this section, I present the implications of the findings discussed in the previous sections and provide recommendations to faculty developers and higher education universities.

5.5.1 Recommendations to faculty developers

The findings from this study will contribute to the understanding of faculty developers on how to design workshops that will help instructors integrate technology into their courses. It was observed that a basic understanding of student-centered learning might aid instructors while developing TPACK. The development of TPACK, as seen in this study, involved three different phases. Instructors who had previously taught courses in a student-centered learning environment were seen to possess an intermediate level of pedagogical content knowledge, which had supported the instructors as they started the second phase of constructing TPACK. The professional development program implemented in this study was scheduled for 6-weeks with the participants meeting for full day sessions three times a week. Few of the participants needed 2 weeks of additional time to complete the final deliverables. If faculty developers are provided with shorter time to facilitate a workshop on technology integration, they could split the workshop into two different phases. The first phase would include a basic introduction to student-centered learning that would help the instructors to develop content and pedagogical knowledge. The second phase will introduce technology tools to the instructors and help them integrate the technological knowledge with content knowledge, pedagogical knowledge, and pedagogical content knowledge. It would be recommended that the instructors after completing phase 1, should teach the course for a semester in a student-centered classroom, before they attend the phase two of the workshop as their prior teaching experience, as seen in this study, would assist them in the development of TPACK. Reflective prompts could be provided to the instructors during the semester to help them critically reflect and closely examine students' experience in the course. The reflection exercises would the help participants be better prepared as they would now understand how and why technology tools should be implemented in their courses.

The participants developed TPACK during the 6-week program while working on the final design project. The learning by design approach was essential to help the participants engage in critical thinking and reflective practice. Participants had to make design-based decisions by taking the experiences of students into consideration. Faculty developers could provide participants with a few exercises that would help them to start reflecting on the course prior to the start of the faculty development program. During the program, the participants should be encouraged to ask critical questions to identify issues that students might have faced in the course. The critical questions along with activities on concept mapping would help the instructors to form mental models and assist in the development of TPACK. Pre-existing surveys could be used to measure the technology self-efficacy of the instructors and additional scaffolding should be done for instructors with low scores. Low technology self-efficacy could inhibit the development of technological knowledge and restrict effective integration of technology into courses (Hosseini & Tee, 2012). It was observed during the professional development program that the development of technology-mediated resources could be time consuming. Faculty developers must therefore provide participants with sufficient time to successfully integrate technology tools into their course.

Participants used the CoP established in this study to exchange knowledge of TPACK, clarify misconceptions, and provide feedback to each other. The diversity in prior teaching experience helped the participants to provide different perspectives on how students learn in their course. The presence of instructors from the Computer Science and Engineering department benefited the other participants when they needed support with identifying technology tools for their course. Faculty developers should assist the CoP members to initiate additional activities that could be implemented after the end of the program. This will help the CoP evolve to the coalescing and maturing stage. After the completion of the faculty development program, faculty developers could serve as mentors to the members of the CoP through eLearning platforms (Figg & Jaipal-Jamani, 2017) to ensure the sustainability of the CoP. After serving as mentors to the CoP during the coalescing stage, faculty developers can gradually end their association later as the CoP transitions to the maturing stage. The extended interaction after the programs could contribute to the sustainable development of faculty development efforts inside institutions. By ensuring the successful integration of technology tools and mentoring the participants after the program, faculty developers can move a step further to evaluate the professional development program by measuring the impact on students' learning outcomes. The impact on students' learning outcomes is considered as the highest level of evaluating professional development programs and often perceived to be ultimate goal of facilitating faculty development programs (Guskey, 2000).

5.5.2 Recommendations to higher education institutions

Most of the universities, right now, have transitioned to using technology such as learning management systems and cloud-based email system to facilitate teaching and learning (Dobre, 2015). However, prior research indicates that the adoption of technology within instruction by faculty in higher education continues to be uncommon (Adams Becker et al., 2017). Factors that have been identified as barriers to faculty adoption of technology tools in instruction include the lack of time to learn about new technologies, limited technology skills, and lack of institutional support (Figg & Jaipal-Jamani, 2017). Similar findings were reported in this study as the participants mentioned the development of technology-based resources to be a very time-consuming process. Additionally, majority of the faculty in higher education have multiple other responsibilities such as conducting research and engaging in service-related activities. Prior to the start of the 6-week professional development program, the administration at the site of the study reduced the number of courses that were expected to be taught by the participants during the semester. The participants were allowed to teach two courses instead of three to provide them with additional time to focus on the professional development activities. The additional time helped the participants as they often had to work on completing their final design project outside of the professional development sessions. It is therefore recommended that higher education universities provide faculty with incentives and additional support resources to promote the integration of technology into courses. Universities can support their faculty by organizing regular professional development opportunities, establishing local support networks through a community of practice model, and hiring technology specialists who have high technological knowledge focusing on education.

The participants in this study reported to encounter challenges as they were identifying and implementing advanced technology tools into their courses. The availability of a technology expert could support the faculty by addressing their technical needs as they re-design their course using technology tools. The presence of a technology expert would also save the faculty's time in re-designing the course as they would not need to spend a lot of time on developing the technology-based resources by themselves. A prior study that investigated the experiences of faculty who integrated technology tools into their courses revealed that the support of eLearning specialists greatly contributed to the faculty's capacity to teaching with technology (Figg & Jaipal-Jamani, 2017). The support of eLearning specialists helped the faculty build knowledge of how to teach with technology, design technology-enhanced learning activities, and promoted a comfort level with using technology tools during instruction.

To promote large scale integration of technology in courses, universities can establish collaborative learning groups in the form of communities of practice where faculty interested in integrating technology tools into their instruction could meet and engage in meaningful discussions. Including the faculty who have already developed TPACK in the community of practice could support the other members as they share their prior experiences of integrating technology into their respective courses. The use of the community of practice model could promote sustainable professional development efforts by agreeing upon a common domain of interest, practices to evolve in the domain, and set of shared norms that ensure that the community members respect and learn from each other. Universities can provide monetary or non-monetary benefits to invoke interest and encourage faculty to actively participate in the community of practice. The lack of incentives and recognition to innovate pedagogical practices have been widely noted as a key research for lack the innovation in higher education instruction (Cohen & Ball, 2007; Fairweather, 2008).

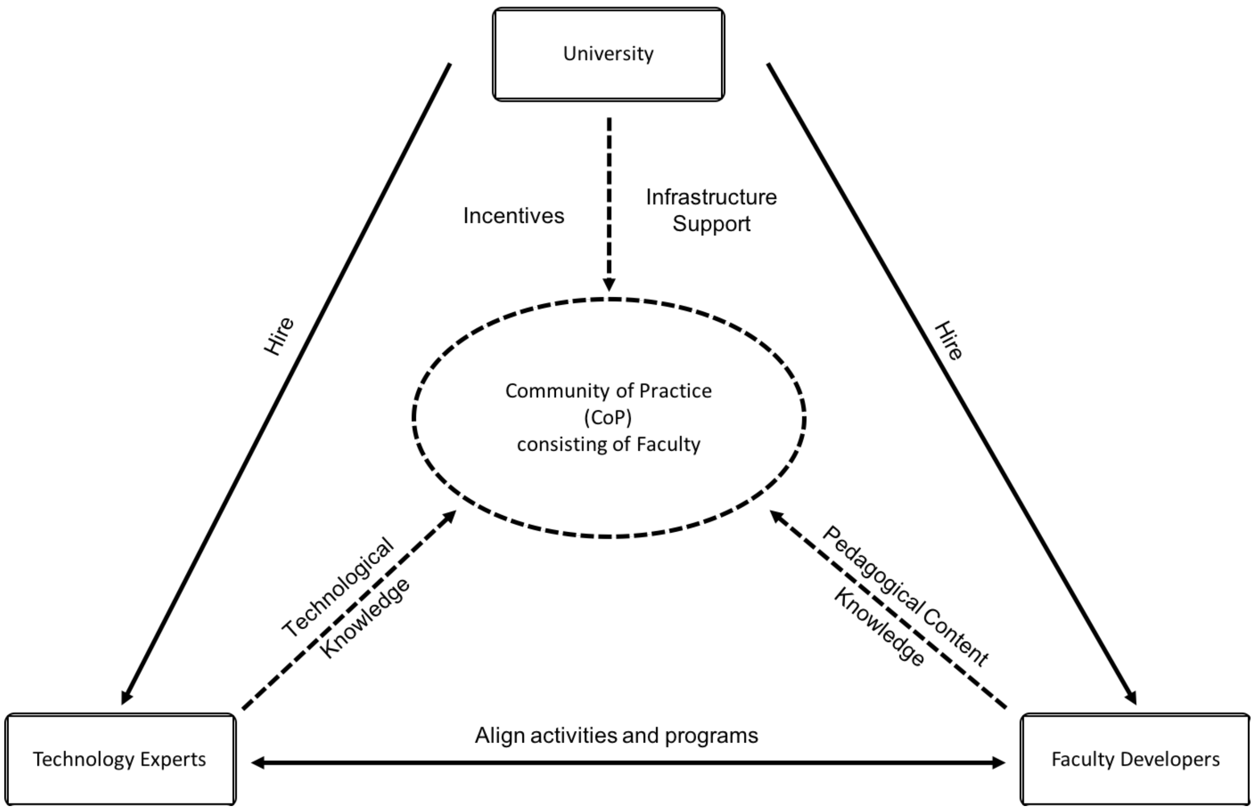

Figure 21 – Model to promote sustainable large-scale integration of technology-based instruction in universities

Figure 21 depicts a model to promote large scale technology-based instruction inside a university. The model is applicable to universities whose faculty are expected to teach and conduct research as part of their responsibilities. The university need to have financial resources to support the initiative through incentives and necessary infrastructure (licenses to technology tools, etc.). The model recommends universities to hire faculty developers and technology experts who could support faculty as they learn to integrate technology tools into their course. The faculty developers can support the faculty in developing pedagogical content knowledge and help them understand how the pedagogy should be adapted depending on the course objectives. Faculty through pedagogical content knowledge would also develop an understanding of the difficult concepts and misconceptions in the course and how the different concepts in the course should be represented. The faculty after developing pedagogical content knowledge can take help of the technology experts to build awareness of the various technology tools that are available to represent their course content, implement the pedagogical activities identified, and help address the learning needs of the students. All the faculty development efforts should be facilitated through the formation of a CoP where the members of the community can support the faculty as they work towards integrating technology tools. The CoP can include both old and new members which would allow meaningful exchange of knowledge. The university should support the CoPs activities by providing the necessary infrastructure and incentives that would motivate the members to actively participate in the community.

5.7 Limitations

One of the major limitations of the study is the context of the institution in India where the 6-week professional development program was implemented. KG Reddy College of Engineering and Technology is affiliated to Jawaharlal Nehru Technological University Hyderabad (JNTUH), which is a regional university that prescribes the curriculum and academic regulations to all affiliated institutions. Due to the lack of autonomy in designing the curriculum and thereby the course content being taught, the participants chose a course (during the faculty development) whose syllabus was prescribed by the JNTUH. While the participants had complete autonomy over the pedagogy and technology tools they integrated in the final design project, they did not get to decide the content for the course. While working on the final design project, the participants did not take the assessment of the courses into consideration as the regional university was responsible to develop and conduct the assessments for all the affiliated institutions. The experiences of the faculty in this research study were therefore limited with respect to the design decisions they had to make for the content and assessments of their course.

Another limitation of the study is the low technology self-efficacy of many of the participants. Participants encountered many challenges while developing the technological content and technological pedagogical knowledge for their course. Due to their low technology self-efficacy, they reported to face challenges while selecting the appropriate technology tools. This could have limited the participants' experience to be less innovative while re-designing their course during the 6-week program. The low technology self-efficacy was a result of the participants' lack of prior experiences with using computer-mediated technology tools. Majority of the participants did not own a personal laptop and only used the PCs made available to them at the institution. While the findings of this study could be transferable to other developing countries where the faculty have low access to computers-based resources, the experiences of the faculty might differ in developed countries where they might have large number of resources available. Faculty with high technology self-efficacy could be open to experiment with varied technology tools that influence their design choices for the final project.

Another limitation is the structure of the CoP that was established prior to the start of the 6-week program. The CoP was formed as an internal community among the faculty in the institution and many participants mentioned to benefit from it. The participants on multiple occasions met with the other CoP members outside of the professional development sessions for support. Faculty development programs that consist of faculty from different institutions might be unable adopt a similar structure and therefore have limited sources of help-seeking resources. Faculty developers will have to include additional mechanisms that will allow the CoP members to interact outside of the professional development sessions.

The final limitation of the study is the possibility of any potential bias that might have occurred during the data collection process. The power differential that existed between me and the participants as a result of my relationship with the board members of the institution could have biased the participants responses in the study. Prior to the start of the 6-week program, I had multiple interactions with the participants to let them know that the experiences captured through their participation in the study would be kept confidential and would not be shared with anyone from the institution. I made sure to emphasize to the participants that my study was not evaluating their participation in the professional development program and was focused on understanding how they developed TPACK. It was made clear that the results of this study would be dependent on their honest responses and it would be appreciated if they are truthful during the data collection process. In spite of the many steps taken, I cannot completely refute the possibility of any bias in the participants responses and therefore consider this to be one of the limitations of my study.

5.8 Conclusion

The results in this study provide significant insight into how engineering faculty developed TPACK as a part of a 6-week professional development program. The findings indicated that the faculty developed TPACK in three phases. In the first phase, the faculty build knowledge of the basic sub-domains of TPACK – content knowledge, pedagogical knowledge, and technological knowledge. The faculty then situated the knowledge of the sub-domains into their respective courses to form pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge. In the third and last phase, faculty developed TPACK by meta-conceptually thinking about how their knowledge of the intersecting sub-domains could help address some of the limitations they are experiencing as an instructor and the learning needs of the students. The development of TPACK was examined as the faculty worked on a final design project where they re-designed an existing course by integrating appropriate technology tools. The 6-week program incorporated a learning by design approach to provide faculty with opportunities to critically think and develop an understanding of how and why technology could be effectively integrated into their courses. The learning by design approach was observed to be play an important role in the process of development of TPACK.

The findings suggested that the faculty had challenges while engaging in critical thinking and needed to support to learn to ask critical questions. Majority of the participants also had trouble while selecting appropriate technology tools as a result of low technology self-efficacy. A CoP was established prior to the start of the 6-week program and the members of the CoP were observed to be utilized as one of the major help-seeking resources. The formation of CoPs could be a potential solution to sustainable faculty development efforts in institutions, as the CoP members can now continue interacting and developing TPACK after the completion of the faculty development programs. The inclusion of faculty with diverse prior teaching experience could enrich the discussions among the members in the CoP. The analysis in this study was carried out through an in-depth qualitative data analysis using semi-structured interviews, faculty reflection journals, and field notes taken during the faculty development sessions. The use of qualitative data analysis was found to be an effective approach to evaluate faculty development programs as the data sources would allow us to measure how the participants' used of the new knowledge and skills and applied it to their courses. Faculty developers could later track the impact on students' learning outcomes by doing a pre-and-post comparison of students grades who took the course before and after the faculty development program. Both the measurement of faculty's use of new knowledge and skills and impact on students' learning outcomes were reported to be the highest levels of successfully evaluating faculty development programs (Guskey, 2002). The study provided recommendations for faculty developers and higher education universities on how to implement large scale efforts that would help instructors successfully integrate technology tools into their courses.

REFERENCES

Adams Becker, S., Cummins, M., Davis, A., Freeman, A., Hall Giesinger, C., Ananthanarayanan, V., EDUCAUSE. (2017). *NMC Horizon Report: 2017 Higher Education Edition*. New Media Consortium.

Affiliation Procedure and Regulations. (2018). University Academic Audit Cell, Jawaharlal Nehru Technological University Hyderabad.

Allee, V. (2000). Knowledge networks and communities of practice. *OD Practitioner*, *32*(4), 4–13.

Alsofyani, M. M., Aris, B. bin, Eynon, R., & Majid, N. A. (2012). A Preliminary Evaluation of Short Blended Online Training Workshop for TPACK Development Using Technology Acceptance Model. *Turkish Online Journal of Educational Technology - TOJET*, *11*(3), 20–32.

Alvarez, I., Guasch, T., & Espasa, A. (2009). University teacher roles and competencies in online learning environments: a theoretical analysis of teaching and learning practices. *European Journal of Teacher Education*, *32*(3), 321–336. https://doi.org/10.1080/02619760802624104

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: an instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning*, *21*(4), 292–302. https://doi.org/10.1111/j.1365-2729.2005.00135.x

Angeli, Charoula, & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, *52*(1), 154–168. https://doi.org/10.1016/j.compedu.2008.07.006

Arnold, D. (2004). *Science, technology and medicine in colonial India* (Vol. 5). Cambridge: Cambridge University Press.

Barab, S., & Squire, K. (2004). Design-Based Research: Putting a Stake in the Ground. *Journal of the Learning Sciences*, *13*(1), 1–14. https://doi.org/10.1207/s15327809jls1301_1

Behar-Horenstein, L. S., Schneider-Mitchell, G., & Graff, R. (2009). Promoting the Teaching of Critical Thinking Skills Through Faculty Development. *Journal of Dental Education*, *73*(6), 665–675.

Booker, C. (2018). Ohio State students equipped with iPad toolkit as orientation begins [Ohio State News]. Retrieved February 28, 2019, from Ohio State News website: https://news.osu.edu/ohio-state-students-equipped-with-ipad-toolkit-as-orientation-begins/

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brewer, W. F. (1987). Schemas versus mental models in human memory. In *Modelling cognition* (pp. 187–197). Oxford, England: John Wiley & Sons.

Bromley, D. B. (1986). *The case-study method in psychology and related disciplines*. New York, NY: Wiley.

Carter, M. (2009). Communities of Practice for Professional Development. *Exchange (19460406)*, (190), 20–24.

Changes in Approval Process Handbook 2018 - 2019. (2018). All India Council for Technical Education.

Chauhan, C. P. S. (2008). Education and caste in India. *Asia Pacific Journal of Education*, *28*(3), 217–234. https://doi.org/10.1080/02188790802267332

Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist*, *49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

Cohen, D. K., & Ball, D. L. (2007). Educational innovation and the problem of scale. *Scale up in Education: Ideas in Principle*, *1*, 19–36.

Cox, S., & Graham, C. R. (2009). Diagramming TPACK in Practice: Using an Elaborated Model of the TPACK Framework to Analyze and Depict Teacher Knowledge. *TechTrends: Linking Research & Practice to Improve Learning*, *53*(5), 60–69. https://doi.org/10.1007/s11528-009-0327-1

Creswell, J. W., & Miller, D. L. (2000). Determining Validity in Qualitative Inquiry. *Theory Into Practice*, *39*(3), 124–130. https://doi.org/10.1207/s15430421tip3903_2

Crompton, H. (2015). Pre-service Teachers' Developing Technological Pedagogical Content Knowledge (TPACK) and Beliefs on the Use of Technology in the K-12 Mathematics Classroom: A Review of the Literature. In *Technological Pedagogical Content Knowledge* (pp. 239–250). https://doi.org/10.1007/978-1-4899-8080-9_12

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science*, *35*(8), 982–1003. https://doi.org/10.1287/mnsc.35.8.982

Dearing, J. W. (2009). Applying diffusion of innovation theory to intervention development. *Research on Social Work Practice*, *19*(5), 503–518.

DeBoer, J., Stites, N., Berger, E., Rhoads, J., Krousgrill, C., Nelson, D., Evenhouse, D. (2016). Work in Progress: Rigorously Assessing the Anecdotal Evidence of Increased Student Persistence in an Active, Blended, and Collaborative Mechanical Engineering Environment. *ASEE Conference & Exposition, New Orleans, LA*. https://doi.org/10.18260/p.27032

Dobre, L. (2015). Learning Management Systems for Higher Education - An Overview of Available Options for Higher Education Organizations. *Procedia - Social and Behavioral Sciences*, *180*, 313–320. https://doi.org/10.1016/j.sbspro.2015.02.122

Donnelly, R., & Maguire, T. (2018). Supporting Teaching and Learning Transformations through the National Professional Development Framework: Establishing and Recognising an Inclusive Community of Practice for All who Teach in Irish Higher Education. *AISHE-J: The All Ireland Journal of Teaching & Learning in Higher Education*, *10*(1), 3391–33917.

Ellis, R. A., Pardo, A., & Han, F. (2016). Quality in blended learning environments – Significant differences in how students approach learning collaborations. *Computers & Education*, *102*, 90–102. https://doi.org/10.1016/j.compedu.2016.07.006

Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, *70*(1), 113–136. https://doi.org/10.1348/000709900158001

Evenhouse, D., Patel, N., Gerschutz, M., Stites, N. A., Rhoads, J. F., Berger, E., & DeBoer, J. (2017). Perspectives on pedagogical change: instructor and student experiences of a newly implemented undergraduate engineering dynamics curriculum. *European Journal of Engineering Education*, *0*(0), 1–15. https://doi.org/10.1080/03043797.2017.1397605

Fairweather, J. (2008). Linking evidence and promising practices in science, technology, engineering, and mathematics (STEM) undergraduate education. *Board of Science Education, National Research Council, The National Academies, Washington, DC*.

Feldman, A., Altrichter, H., Posch, P., & Somekh, B. (2018). *Teachers investigate their work: An introduction to action research across the professions*. Routledge.

Figg, C., & Jaipal-Jamani, K. (2017, March 5). *Developing TPACK in Higher Education Faculty: An eLearning Mentor Strategy*. 2319–2323. Retrieved from https://www.learntechlib.org/primary/p/177525/

Friedman, J. (2016). Law Schools Experiment With Partially Online Learning. Retrieved March 1, 2019, from US News & World Report website: https://www.usnews.com/education/best-graduate-schools/top-law-schools/articles/2016-11-07/law-schools-experiment-with-partially-online-learning

Fullan, M. (2009). Large-scale reform comes of age. *Journal of Educational Change*, *10*(2–3), 101–113.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What Makes Professional Development Effective? Results From a National Sample of Teachers. *American Educational Research Journal*, *38*(4), 915–945. https://doi.org/10.3102/00028312038004915

Gedik, N., Kiraz, E., & Yaşar, Ö. (2012). The Optimum Blend: Affordances and Challenges of Blended Learning For Students. *Turkish Online Journal of Qualitative Inquiry*, *3*(3), 102–117.

Gill, L., & Dalgarno, B. (2017). A qualitative analysis of pre-service primary school teachers' TPACK development over the four years of their teacher preparation programme. *Technology, Pedagogy and Education*, *26*(4), 439–456. https://doi.org/10.1080/1475939X.2017.1287124

Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report*, *8*(4), 597–606.

Golding, C. (2011). Educating for critical thinking: thought-encouraging questions in a community of inquiry. *Higher Education Research & Development*, *30*(3), 357–370. https://doi.org/10.1080/07294360.2010.499144

Graham, R., Burgoyne, N., Cantrell, P., Smith, L., St Clair, L., & Harris, R. (2009). TPACK Development in Science Teaching: Measuring the TPACK Confidence of Inservice Science Teachers. *TechTrends*, *53*(5), 70–79.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education* (Vol. 41). Teachers College Press New York.

Guest, G., MacQueen, K. M., & Namey, E. E. (2011). *Applied thematic analysis*. Thousand Oakes, CA: Sage Publications.

Guskey, T. R. (2000). *Evaluating professional development*. Corwin Press.

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching*, *8*(3), 381–391.

Heikkilä, A., & Lonka, K. (2006). Studying in higher education: students' approaches to learning, self-regulation, and cognitive strategies. *Studies in Higher Education*, *31*(1), 99–117. https://doi.org/10.1080/03075070500392433

Holden, H., & Rada, R. (2011). Understanding the Influence of Perceived Usability and Technology Self-Efficacy on Teachers' Technology Acceptance. *Journal of Research on Technology in Education*, *43*(4), 343–367. https://doi.org/10.1080/15391523.2011.10782576

Horzum, M. B., & Gungoren, O. C. (2012). A model for beliefs, tool acceptance levels and web pedagogical content knowledge of science and technology preservice teachers towards web based instruction. *Turkish Online Journal of Distance Education*, *13*(3).

Hosseini, Z., & Tee, M. Y. (2012). Conditions influencing development of teachers' knowledge for technology integration in teaching. *International Magazine on Advances in Computer Science and Telecommunications*, *3*(1), 91–101.

Hubball, H., Collins, J., & Pratt, D. (2005). Enhancing Reflective Teaching Practices: Implications for Faculty Development Programs. *Canadian Journal of Higher Education*, *35*(3), 57–81.

Hughes, J. (2008). *In-service Teachers' use and development of TPCK within technology inquiry groups*. Presented at the Symposium paper presented at the annual American educational research association conference.

Hughes, Joan. (2005). The Role of Teacher Knowledge and Learning Experiences in Forming Technology-Integrated Pedagogy. *Journal of Technology & Teacher Education*, *13*(2), 277–302.

Jaipal-Jamani, K., & Figg, C. (2015a). A Case Study of a TPACK-Based Approach to Teacher Professional Development: Teaching Science With Blogs. *Contemporary Issues in Technology & Teacher Education*, *15*(2), 161–200.

Jaipal-Jamani, K., & Figg, C. (2015b). The Framework of TPACK-in-Practice: Designing Content-Centric Technology Professional Learning Contexts to Develop Teacher Knowledge of Technology-enhanced Teaching (TPACK). In *Technological Pedagogical Content Knowledge* (pp. 137–163). https://doi.org/10.1007/978-1-4899-8080-9_7

Johnson, L., Adams Becker, S., Cummins, M., Freeman, A., Ifenthaler, D., & Vardaxis, N. (2013). *Technology Outlook for Australian Tertiary Education 2013-2018: An NMC Horizon Project Regional Analysis.* Austin, TX: ERIC.

Johnson-Laird, P. N. (1980). Mental Models in Cognitive Science. *Cognitive Science*, *4*(1), 71–115. https://doi.org/10.1207/s15516709cog0401_4

Ju Joo, Y., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *Journal of Educational Technology & Society*, *21*(3), 48–59.

Kabakci Yurdakul, I., Odabasi, H. F., Kilicer, K., Coklar, A. N., Birinci, G., & Kurt, A. A. (2012). The development, validity and reliability of TPACK-deep: A technological pedagogical content knowledge scale. *Computers & Education*, *58*(3), 964–977. https://doi.org/10.1016/j.compedu.2011.10.012

Kaddoura, M. (2013). Think Pair Share: A teaching Learning Strategy to Enhance Students' Critical Thinking. *Educational Research Quarterly; West Monroe*, *36*(4), 3–24.

Kandakatla, R., Rhoads, J. F., Berger, E., & DeBoer, J. (2019). Student Perspectives on the Learning Resources in an Active, Blended, and Collaborative (ABC) Learning Environment in a Core Undergraduate Engineering Course. *Manuscript Submitted for Publication.*

Kane, M., & Trochim, W. M. K. (2007). *Concept mapping for planning and evaluation*. In *Concept Mapping for Planning and Evaluation*. Thousand Oaks, CA: Sage Publications, Inc.

Kaplan, A. M., & Haenlein, M. (2016). Higher education and the digital revolution: About MOOCs, SPOCs, social media, and the Cookie Monster. *Business Horizons*, *59*(4), 441–450. https://doi.org/10.1016/j.bushor.2016.03.008

Kinsella, E. A. (2010). Professional knowledge and the epistemology of reflective practice: The Epistemology of Reflective Practice. *Nursing Philosophy*, *11*(1), 3–14. https://doi.org/10.1111/j.1466-769X.2009.00428.x

Knafl, K., Deatrick, J., Gallo, A., Holcombe, G., Bakitas, M., Dixon, J., & Grey, M. (2007). The analysis and interpretation of cognitive interviews for instrument development. *Research in Nursing & Health*, *30*(2), 224–234. https://doi.org/10.1002/nur.20195

Koehler, M. J., Mishra, P., & Cain, W. (2013). What Is Technological Pedagogical Content Knowledge (TPACK)? *The Journal of Education*, *193*(3), 13–19.

Koehler, M. J., Mishra, P., & Hershey, K. (2004). With a Little Help From Your Students: A New Model for Faculty Development and Online Course Design. *Journal of Technology & Teacher Education*, *12*(1), 25–55.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education*, *49*(3), 740–762. https://doi.org/10.1016/j.compedu.2005.11.012

Koehler, M., & Mishra, P. (2009). What is Technological Pedagogical Content Knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60–70.

Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes. *Journal of Educational Computing Research*, *55*(2), 172–196. https://doi.org/10.1177/0735633116656848

Koh, J. h. l., Chai, C. s., & Tsai, C. c. (2010). Examining the technological pedagogical content knowledge of Singapore pre-service teachers with a large-scale survey. *Journal of Computer Assisted Learning*, *26*(6), 563–573. https://doi.org/10.1111/j.1365-2729.2010.00372.x

Krauskopf, K., Zahn, C., & Hesse, F. W. (2015). Cognitive Processes Underlying TPCK: Mental Models, Cognitive Transformation, and Meta-conceptual Awareness. In *Technological Pedagogical Content Knowledge* (pp. 41–61). https://doi.org/10.1007/978-1-4899-8080-9_3

Krishna, A. (2014). Examining the Structure of Opportunity and Social Mobility in India: Who Becomes an Engineer? *Development and Change*, *45*(1), 1–28. https://doi.org/10.1111/dech.12072

Larrivee, B. (2000). Transforming Teaching Practice: Becoming the critically reflective teacher. *Reflective Practice*, *1*(3), 293–307. https://doi.org/10.1080/713693162

López-Pérez, M. V., Pérez-López, M. C., & Rodríguez-Ariza, L. (2011). Blended learning in higher education: Students' perceptions and their relation to outcomes. *Computers & Education*, *56*(3), 818–826. https://doi.org/10.1016/j.compedu.2010.10.023

López-Vargas, O., Duarte-Suárez, L., & Ibáñez-Ibáñez, J. (2017). Teacher's computer self-efficacy and its relationship with cognitive style and TPACK, Teacher's computer self-efficacy and its relationship with cognitive style and TPACK. *Improving Schools*, *20*(3), 264–277. https://doi.org/10.1177/1365480217704263

Loucks-Horsley, S., Stiles, K. E., Mundry, S., & Hewson, P. W. (2009). *Designing professional development for teachers of science and mathematics*. Corwin Press.

Lundeberg, M., Bergland, M., Klyczek, K., & Hoffman, D. (2003). Using action research to develop preservice teachers' beliefs, knowledge and confidence about technology [Electronic version]. *Journal of Interactive Online Learning*, *1*(4).

Margerum-Leys, J. (2001). *Teacher knowledge of educational technology: A case study of student teacher/mentor teacher pairs* (Ph.D., University of Michigan). Retrieved from https://search.proquest.com/docview/275871024/abstract/991798721FB64B27PQ/1

Margerum-Leys, J., & Marx, R. W. (2000). *Teacher Knowledge of Educational Technology: A Study of Student Teacher/Mentor Teacher Pairs*. Presented at the American Educational Research Association Annual Meeting.

Matherson, L. H., Wilson, E. K., & Wright, V. H. (2014). Need TPACK? Embrace Sustained Professional Development. *Delta Kappa Gamma Bulletin*, *81*(1), 45–52.

McArdle, K., & Ackland, A. (2007). The demands of the double shift: communities of practice in continuing professional development. *Journal of Vocational Education & Training*, *59*(1), 107–120. https://doi.org/10.1080/13636820601145739

Merriam, S. B. (1998). *Qualitative Research and Case Study Applications in Education. Revised and Expanded from "Case Study Research in Education."* San Francisco, CA: Jossey-Bass Publishers.

Minds, A. (2016). National Employability Report 2016-Aspiring Minds. *Annual Report*.

Mishra, P. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, *108*(6), 1017–1055.

Mishra, P., & Koehler, M. (2003). *Not "what" but "how": Becoming design-wise about educational technology*.

Mohanty, A., & Dash, D. (2016). Engineering Education in India: Preparation of Professional Engineering Educators. *Journal of Human Resource and Sustainability Studies*, *04*, 92. https://doi.org/10.4236/jhrss.2016.42011

Murthy, S., Iyer, S., & Warriem, J., (2015). ET4ET: A Large-Scale Faculty Professional Development Program on Effective Integration of Educational Technology. *Journal of Educational Technology & Society*, *18*(3), 16–28.

Niess, M., & Garofalo, J. (2006). *Preparing teachers to teach mathematics with technology: key issues, concerns and research questions*. 3796–3801. Association for the Advancement of Computing in Education (AACE).

Niess, M. L. (2011). Investigating TPACK: Knowledge Growth in Teaching with Technology. *Journal of Educational Computing Research*, *44*(3), 299–317. https://doi.org/10.2190/EC.44.3.c

Olofson, M. W., Swallow, M. J. C., & Neumann, M. D. (2016). TPACKing: A constructivist framing of TPACK to analyze teachers' construction of knowledge. *Computers & Education*, *95*, 188–201. https://doi.org/10.1016/j.compedu.2015.12.010

Pantelidis, V. S. (2010). Reasons to Use Virtual Reality in Education and Training Courses and a Model to Determine When to Use Virtual Reality. *Themes in Science and Technology Education*, *2*(1–2), 59–70.

Patton, M. Q. (2002). Two Decades of Developments in Qualitative Inquiry: A Personal, Experiential Perspective. *Qualitative Social Work*, *1*(3), 261–283. https://doi.org/10.1177/1473325002001003636

Perkins, D. N. (2010). *Making learning whole: How seven principles of teaching can transform education*. John Wiley & Sons.

Pierson, M. E. (2001). Technology Integration Practice as a Function of Pedagogical Expertise. *Journal of Research on Computing in Education*, *33*(4), 413–430. https://doi.org/10.1080/08886504.2001.10782325

Pintrich, P. R. (1999). The role of motivation in promoting and sustaining self-regulated learning. *International Journal of Educational Research*, *31*(6), 459–470.

Polly, D. (2011). Developing Teachers' Technological, Pedagogical, and Content Knowledge (TPACK) through Mathematics Professional Development. *International Journal for Technology in Mathematics Education*, *18*(2), 83–96.

Power, C. M., Thorndyke, L. E., Milner, R. J., Lowney, K., Irvin, C. G., Fonseca-Kelly, Z., … Connelly, M. T. (2018). Advancing Professional Development Through a Community of Practice: the New England Network for Faculty Affairs. *Journal of Continuing Education in the Health Professions*, *38*(1), 73. https://doi.org/10.1097/CEH.0000000000000186

Reeves, T. C., Herrington, J., & Oliver, R. (2005). Design research: A socially responsible approach to instructional technology research in higher education. *Journal of Computing in Higher Education*, *16*(2), 96–115. https://doi.org/10.1007/BF02961476

Rhoads, J., Nauman, E., Holloway, B., & Krousgrill, C. (2014). The Purdue Mechanics Freeform Classroom: A New Approach to Engineering Mechanics Education. *121st ASEE Annual Conference & Exposition, Indianapolis, IN.* https://peer.asee.org/23174

Robinson, O. C. (2014). Sampling in Interview-Based Qualitative Research: A Theoretical and Practical Guide. *Qualitative Research in Psychology*, *11*(1), 25–41. https://doi.org/10.1080/14780887.2013.801543

Sancar Tokmak, H. (2015). Pre-service teachers' perceptions on TPACK development after designing educational games. *Asia-Pacific Journal of Teacher Education*, *43*(5), 392–410. https://doi.org/10.1080/1359866X.2014.939611

Schnotz, W., & Wagner, I. (2018). Construction and elaboration of mental models through strategic conjoint processing of text and pictures. *Journal of Educational Psychology*, *110*(6), 850–863. https://doi.org/10.1037/edu0000246

Self Assessment Report for Undergraduate Engineering Programs. (2015). National Board of Accreditation (NBA).

Shaw, K. E. (1978). Understanding the Curriculum: the Approach through Case Studies. *Journal of Curriculum Studies*, *10*(1), 1–17. https://doi.org/10.1080/0022027780100102

Shinde, S. (2018). Now, AICTE certificate programme mandatory for engineering teachers - Times of India. Retrieved October 18, 2018, from The Times of India website: https://timesofindia.indiatimes.com/city/pune/now-aicte-certificate-programme-mandatory-for-engineering-teachers/articleshow/65479798.cms

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.2307/1175860

Smith, A. M., Hurst, J., & Murakami, E. (2016). Building a Community of Practice in a Teacher Preparation Initiative. *International Journal of Progressive Education*, *12*(3), 78–90.

So, H.-J., & Brush, T. A. (2008). Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: Relationships and critical factors. *Computers & Education*, *51*(1), 318–336. https://doi.org/10.1016/j.compedu.2007.05.009

Sorcinelli, M. D., Austin, A. E., & Eddy, P. L. (2006). *Creating the future of faculty development: Learning from the past, understanding the present* (Vol. 59). Jossey-Bass.

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., … Young, A. M. (2018). Anatomy of STEM teaching in North American universities. *Science*, *359*(6383), 1468–1470. https://doi.org/10.1126/science.aap8892

Stake, R. E. (1995). *The art of case study research*. Thousand Oakes, CA: Sage Publications.

Stark, A. M., & Smith, G. A. (2016, May 15). Communities of Practice as Agents of Future Faculty Development [Text]. Retrieved January 6, 2019, from https://www.ingentaconnect.com/contentone/nfp/jfd/2016/00000030/00000002/art00007

Stover, S., & Veres, M. (2013). TPACK in Higher Education: Using the TPACK Framework for Professional Development. *Global Education Journal*, *2013*(1), 93–110.

Streveler, R. A., Smith, K. A., & Pilotte, M. (2012). Aligning course content, assessment, and delivery: Creating a context for outcome-based education. In *Outcome-based science, technology, engineering, and mathematics education: Innovative practices* (pp. 1–26). IGI Global.

Subbarao, E. C. (2013). India's higher engineering education: opportunities and tough choices. *Current Science*, *104*(1), 55–66.

Subramanian, B. (2015). Engineering Education in India: A Comprehensive Overview. In *International Perspectives on Engineering Education* (pp. 105–123). Springer.

Subramanian, L. (2010). *History of India, 1707-1857*. New Delhi: Orient Blackswan.

Surry, D. W. (2010). *Technology Integration in Higher Education: Social and Organizational Aspects: Social and Organizational Aspects*. IGI Global.

Svinicki, M. D. (2004). *Learning and motivation in the postsecondary classroom*. Anker Publishing Company.

Thompson, N., & Pascal, J. (2012). Developing critically reflective practice. *Reflective Practice*, *13*(2), 311–325. https://doi.org/10.1080/14623943.2012.657795

Tracy, S. J. (2010). Qualitative Quality: Eight "Big-Tent" Criteria for Excellent Qualitative Research. *Qualitative Inquiry*, *16*(10), 837–851. https://doi.org/10.1177/1077800410383121

Tuti, S., Kandakatla, R., & Khamruddin, S. (2016). Improving Teaching and Learning Process through Establishment of Centre for Engineering Education Development-An initiative at KG College of Engineering and Technology. *Journal of Engineering Education Transformations*, (Special Issue).

Tzavara, A., & Komis, V. (2015). Design and Implementation of Educational Scenarios with the Integration of TDCK: A Case Study at a Department of Early Childhood Education. In *Technological Pedagogical Content Knowledge* (pp. 209–224). https://doi.org/10.1007/978-1-4899-8080-9_10

van As, F. (2018). Communities of practice as a tool for continuing professional development of technology teachers' professional knowledge. *International Journal of Technology and Design Education*, *28*(2), 417–430. https://doi.org/10.1007/s10798-017-9401-8

Varshney, L. R. (n.d.). *Private Engineering Education in India: Market Failures and Regulatory Solutions*. 15.

Vavasseur, C. B., & MacGregor, S. K. (2008). Extending Content-Focused Professional Development through Online Communities of Practice. *Journal of Research on Technology in Education*, *40*(4), 517–536.

Vo, H. M., Zhu, C., & Diep, N. A. (2017). The effect of blended learning on student performance at course-level in higher education: A meta-analysis. *Studies in Educational Evaluation*, *53*, 17–28. https://doi.org/10.1016/j.stueduc.2017.01.002

Waldner, L. S., Widener, M. C., & McGorry, S. Y. (2012). E-service learning: The evolution of service-learning to engage a growing online student population. *Journal of Higher Education Outreach and Engagement*, *16*(2), 123–150.

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, *9*(5), 2–3.

Wenger, E. (2011). *Communities of practice: A brief introduction*. Retrieved from http://scholarsbank.uoregon.edu/xmlui/handle/1794/11736

Wenger, E., McDermott, R. A., & Snyder, W. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Harvard Business Press.

Whitehead, C. (2003). *Colonial educators: the British Indian and colonial education service 1858-1983*. IB Tauris.

Wiggins, G. P., & McTighe, J. (2005). *Understanding by Design*. In *Gale Virtual Reference Library*: *Vol. Expanded 2nd ed*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=133964&site=ehost-live

Wolters, C. A., Shirley, L. Y., & Pintrich, P. R. (1996). The relation between goal orientation and students' motivational beliefs and self-regulated learning. *Learning and Individual Differences*, *8*(3), 211–238.

Yagci, M. (2016). Blended Learning Experience in a Programming Language Course and the Effect of the Thinking Styles of the Students on Success and Motivation. *TOJET : The Turkish Online Journal of Educational Technology; Adapazari*, *15*(4), 32–45.

APPENDIX A. TECHNOLOGY TOOLS INTRODUCED DURING WEEK 3

Technology tools used for social bookmarking and storing notes.

Technology Tools	Description
Diigo	Social bookmarking tools that allows user to research, highlight text information, and take personal notes on web pages found on the internet.
Evernote	Note taking and archiving tool that allows user to take screenshots of full webpages. Evernote could also be used to take notes, include images, audio recording and syncs files across multiple devices.
Mendeley	Management tools that assists in collecting, organizing, and annotating research publications. Mendeley could be used to share recommended references with students.
Zotero	Alternate tool to Mendeley with similar functionality.

Technology tools for brainstorming, concept maps, and flow charts.

Technology Tools	Description
Mindmeister	Allows users to brainstorm and collaboratively create mind maps.
Inspiration9	Allows users to create diagrams, presentations, and outline.
Creately	Visual communication tool that can be used to create flowcharts, Gantt charts, and info-graphics.
Popplet	Technology tools that facilitates collaborative brainstorming and helps users create graphic organizers and concept maps.

Technology tools to create and edit videos.

Technology Tools	Description

Camtasia	Allows users to create and edit audio and video files and publish them on social media platforms.
iMovie	Alternate to Camtasia specifically for mac users.
Movie Maker	Alternate to Camtasia specifically for PC users.
Premier	Alternate to Camtasia but with advanced video editing options.

Technology tools for audio production.

Technology Tools	Description
Audacity	Audio recording, edit, and converting tools. Useful for voice narration
audioBoom	Tool that allows user to easily record, upload, and play audio recording. Provides convenient features to create short audio podcasts and quickly share them.
SoundCloud	Open source tool that provides easy way to record, upload, and playback audio recording.

Technology tools to create presentations.

Technology Tools	Description
Power Point	Most widely used tools that allows users to create slide show by including graphics, pictures, text, and video.
Prezi	Presentation and storytelling tool. Allows users to present information on a virtual canvas using zoom in and zoom out features.
VideoScribe	Allows users to create whiteboard animations (a hand automatically draws an image on your presentation whiteboard).
PowToon	Allows users to create engaging animated presentations
Piktochart	Allows users to create infographics using themes templates

Technology tools for website development.

Technology Tools	Description
Weebly	Allows users to build professional looking websites without coding
Wix	Allows users to build professional looking websites without coding.
WordPress	Allows users to build professional looking websites without coding.

APPENDIX B. SEMI-STRUCTURED INTERVIEW PROTOCOL – WEEK 0

(Interviews would be conducted with participants prior to start of the 6-week program)

1. Please describe in detail your teaching philosophy?
2. Briefly describe what you consider to be a good teaching?
3. Tell me about your prior professional development experiences, particularly those that helped you in your development as an instructor?
4. What are some of the challenges you currently face in your role as an instructor?
5. Describe in detail about some of the pedagogical innovations you implemented in your experience as an instructor?
    a. Clarify: By pedagogical innovations, I mean any innovative strategies you have applied in your classroom to help your students learn better in the course.
    b. Follow up probe: If there are many, mention the one’s that you think aided students in their learning, or one’s you distinctly remember for specific reasons?
6. Have you ever utilized technology tools in the courses you have taught?
    a. Follow up probe: If yes, how?
    b. Follow up probe: If no, why?
7. If given an opportunity, what would you change about your current teaching practices?
8. Is there any else you would like to share about teaching experience?
    a. Follow up probe: Something that would be relevant to the research study

APPENDIX C. SEMI-STRUCTURED INTERVIEW PROTOCOL – WEEK 2

(Interviews would be conducted with participants at the end of the week 2)

1. I am interested in understanding your experience in the faculty development sessions this week? Please describe your experience during the various sessions?

(Clarify: The experience could include your feelings, reactions, interpretations and reflections during the session)

    a. Follow up probe: Is there anything that stands out to you during the understanding of a certain topic or when you were working on an activity?

2. How did your prior teaching experience influence your thought process during the faculty development sessions?
3. Please describe in detail some of the challenges (if any) you faced in the sessions last two weeks?

(Clarify: The challenges you describe could be situations where you repeatedly had trouble understanding of a certain concept or problems faced while completing a certain activity)

    a. Follow up probe: What did you do to overcome the challenge? (if applicable)

4. Did your prior teaching experience help you in your experience while you worked on various activities last two weeks?
5. What aspect of the faculty development did you find most easy and difficult in the last two weeks? And why?

(Clarify: Something that stands out to you or an instance which you felt was significant to the process of finishing your final project)

APPENDIX D. SEMI-STRUCTURED INTERVIEW PROTOCOL – WEEK 4

(Interviews would be conducted with participants at the end of the week 4)

1. I am interested in understanding your experience in the faculty development sessions this week? Please describe your experience during the various sessions?

(Clarify: The experience could include your feelings, reactions, interpretations and reflections during the session)

   a. Follow up probe: Is there anything that stands out to you during the understanding of a certain topic or when you were working on an activity?

2. How did your prior teaching experience influence your thought process during the faculty development sessions?
3. Please describe in detail some of the challenges (if any) you faced in the sessions last two weeks?

(Clarify: The challenges you describe could be situations where you repeatedly had trouble understanding of a certain concept or problems faced while completing a certain activity)

   a. Follow up probe: What did you do to overcome the challenge? (if applicable)

4. Did your prior teaching experience help you in your experience while you worked on various activities last two weeks?
5. What aspect of the faculty development did you find most easy and difficult in the last two weeks? And why?
6. Can you tell me about your experience while you were working on the final project? (Week 6)

(Clarify: Something that stands out to you or an instance which you felt was significant to the process of finishing your final project)

7. What is the process you used while working on the final project this week?

(Clarify: Process could be an order you followed or certain repeated action you carried out while working on the final project)

8. Are you facing any challenges while working towards your final project?

APPENDIX E. SEMI-STRUCTURED INTERVIEW PROTOCOL – WEEK 6

(Interviews would be conducted with participants at the end of the week 6)

1. I am interested in understanding your experience in the faculty development sessions this week? Please describe your experience during the various sessions?

(Clarify: The experience could include your feelings, reactions, interpretations and reflections during the session)

    a. Follow up probe: Is there anything that stands out to you during the understanding of a certain topic or when you were working on an activity?

2. How did your prior teaching experience influence your thought process during the faculty development sessions?
3. Please describe in detail some of the challenges (if any) you faced in the sessions last two weeks?

(Clarify: The challenges you describe could be situations where you repeatedly had trouble understanding of a certain concept or problems faced while completing a certain activity)

    a. Follow up probe: What did you do to overcome the challenge? (if applicable)

4. Did your prior teaching experience help you in your experience while you worked on various activities last two weeks?
5. What aspect of the faculty development did you find most easy and difficult in the last two weeks? And why?
6. Can you tell me about your experience while you were working on the final project?

(Clarify: Something that stands out to you or an instance which you felt was significant to the process of finishing your final project)

7. What is the process you used while working on the final project this week?

(Clarify: Process could be an order you followed or certain repeated action you carried out while working on the final project)

8. Are you facing any challenges while working towards your final project?
9. How did establishing a CoP at the start impact your experience in the last 6 weeks?

Note: Question 9 was included in the interview based on the responses of the participants in week 2 and 4 interviews.

APPENDIX F. GUIDING QUESTIONS FOR FINAL REFLECTION

At the end of the professional development (week 7)

1. How did your teaching philosophy change during and after the professional development?
2. Did you have any Eureka moment during the 6-week professional development?
3. Did your definition of a good teacher change after the professional development? If yes, how?
4. How do you think the professional development experience will impact your students in their learning process? And why?
5. Which component of the professional development experience did you find the most important for your development as an instructor?
6. What were the most challenging moments or tasks during the professional development?
    a. Follow up probe: Did any of them occur as a consequence of your prior teaching experience or philosophy of teaching.
7. Which components of the final project do you think will be most beneficial to students and why?

APPENDIX G. TIPS FOR JOURNAL KEEPING

Tips for Journal Keeping (Feldman, Altrichter, Posch, & Somekh, 2018, pp. 18)

- Journals should be written regularly, at times that fit in with the kind of research question being investigated.
- Each entry should be accompanied by date of the event and contextual information, such as time, location, participants, focus of study, etc.
- Information that will help you develop a more profound understanding of your practice situation and can help you remember it later can and should be included in the research journal.
- Make sure to include your feelings, reactions, interpretations, reflections, ideals and explanations.
- It is recommended to write down a certain incident or memory before you talk to anybody as the conversation might bias your recollection.
- All entries in the journal should be detailed and as self-explanatory as possible. In case of lack of time, you should make a quick note and revisit it later to elaborate on the note.

APPENDIX H. PROMPTS FOR JOURNAL KEEPING

At the end of each day of the Professional Development

1. What was the most challenging moment for you today? And why?
2. What was your Eureka moment for the day?
3. What did you learn today that you think will help in your role as an instructor?
    a. Probe: Something you think (when applied) will help your students learn better in the course?

Week 4 – 6

1. What aspects of your final project did you work on today?
    a. Probe: How will that help your students while learning in the course? Why
2. What are some of the strategies you used to help you complete your final project?
3. Did you have any questions (to yourself or in general) while working on the final project?

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APPENDIX I. IRB APPROVAL

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	DEBOER, JENNIFER J
From:	DICLEMENTI, JEANNIE D, Chair Social Science IRB
Date:	06/27/2018
Committee Action:(2) (3)	Determined Exempt, Category **(2) (3)**
IRB Action Date:	06 / 26 / 2018
IRB Protocol #:	1806020719
Study Title:	Understand the TPACK Development of Engineering Faculty as part of a Professional Developmental Experience

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b).

Before making changes to the study procedures, please submit an Amendment to ensure that the regulatory status of the study has not changed. Changes in key research personnel should also be submitted to the IRB through an amendment.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the

APPENDIX J. APPROVAL TO CONDUCT RESEARCH STUDY

KG REDDY
College of Engineering
& Technology
Approved by AICTE, New Delhi. Affiliated to JNTU.H, Hyderabad.

Date: 20th June, 2018
Place: Hyderabad, India

To
The Institutional Review Board
Purdue University, USA

Respected Madam/Sir,

Subject: Approval to Conduct Research Study,

I am writing this letter to provide our approval to the research study titled "**Understand the TPACK Development of Engineering Faculty as part of a Professional Developmental Experience**". The institution believes that the purpose of the study is aligned with the goals of the institution as the 6-week professional development that is proposed will help our faculty to effectively integrate technologyin to their courses.

I also confirm with you that I have reviewed the research study and the study is appropriate to the cultural context of India. As someone who was born, raised, and worked in India in the past many decades, I assure you that the study is sensitive to the values and principles of Indians and in no way harming the sentiments of the Indian culture.

I have been in touch with Mr. Rohit Kandakatla who is the co-researcher of the study and helped him to identify the participants for the study. We hoped to provide all the support to the researchers and continue a fruitful collaboration.

For any additional questions or clarifications, please feel to contact me by phone or email.

Yours Sincerely,

Prof. R. S. Jahagirdar,
Principal,
KG Reddy College of Engineering and Technology
Email Id: principal@kgr.ac.in
Phone: +91 89789 91991

PRINCIPAL
KG Reddy College of Engineering & Technology
Chilkur(V), Moinabad (M),
R.R. Dist. Telangana.

K.G. Reddy College of Engg. & Tech.
Chilkur (V), Moinabad (M)
R.R. Dist. T.S.

APPENDIX K. CODE BOOK

Codes

CODE – Abbreviated name of the code
Full Code – Full name of code
Definition – Definition of the code
Example – A quote from the participants' responses to provide an example of when to apply the code

CHALLEN_IDEAGEN
CHALLENGE TO GENERATE IDEAS
Participant described struggling while generating ideas for the final design project
The first challenge was deciding about the final project. I wasn't able to think in a way to bring all aspects of the concept map together.

CHALLEN_INTRSCT_TPACK
CHALLENGE TO INTERSECT KNOWLEDGE OF TPACK SUB-DOMAINS
Participants described facing challenges while combining knowledge of content and pedagogy or content and technology or pedagogy and technology
Working with the ICAP framework. I haven't included in the concept map yet as I am still trying to figure out when I should use active, constructive and interactive activities.

CHALLEN_TECH
CHALLENGE WHILE INTEGRATING TECHNOLOGY TOOLS
Participants described facing challenges while integrating technology tools into their final design project. Challenge include identification of technology tools and troubleshooting errors.
Looking at what technology tools we could use for course was challenging. This is something which is still not clear to me. In order to implement those things, we should have an idea. For example, if we want to implement a blog for the course, we need to know how to create a blog and also make sure the design is efficient for students to learn.

CHALLEN_REF
CHALLENGE WHILE REFLECTION
Participant described encountering challenges while engaging in reflection
During the activities, I have been asked to reflect a lot on how I am teaching, why I am teaching in a specific way etc. This has been challenging because I don't have a lot of practice or experience with reflection. I have 10 years of teaching experience, but I have reflected what I did. The idea of reflection was very alien to me. Now that I am trying to do that, it has been a little challenging.

CM_CHALLEN
USING THE CONCEPT MAPPING TOOLS WAS CHALLENGING
Participants described having trouble while using the concept mapping tools
When used the mind mapping software, first I mapped the content. I was confused while developing the concept map for pedagogy and technology. It was a new tool for me, so while learning to use the tool, I had some trouble.

CM_COURSEPLN
CONCEPT MAP TO PREPARE AND PRESENT OVERVIEW OF THE COURSE
Participants described using concept maps to prepare for the course in advance and present the overview of the course to the students.
I realized that by using concept map tools, I can present the course outline to the students in a much effective way. Also, the tool mindmeister allows us to attach content files to each node and that could provide students a more structured way to access the content in a meaningful way.

CM_INTRSCT_TPACK
CONCEPT MAP USED TO INTERSECT KNOWLEDGE OF TPACK SUB-DOMAINS
Participants described the concept mapping activity to help them combine knowledge of content and pedagogy or content and technology or pedagogy and technology
But while working on the concept map, I was able to reflect on which pedagogical technique should be used for which content of the course and why.

COP_CLRF_MSC
COP HELPED TO CLARIFY MISCONCEPTIONS
Participants described the community of practice members helping them to clarify misconceptions during the professional development sessions
When the other participants presented their ideas and how they applied the different concepts to their courses, it helped me contextualize the learning to my own course. When they talk about their courses, I was also able to clarify my own misconceptions.

COP_IDEAGEN
COP PROVIDED SUPPORT WHILE GENERATING IDEAS
Participants reported the CoP members helping them to think about ideas for the final design project
In the last two weeks, I got a lot of assistance from the other participants. They gave me many ideas for my final project.

COP_KNWLD_EX
COP ENABLED EXCHANGE OF KNOWLEDGE

Participants described that the interaction with co-participants resulted in exchange of knowledge. Do not include exchange of technological knowledge

As we approach a peer for support, the other individual might help you and also seek support when required. So, by having such interactions, we can gain more knowledge, and everyone can benefit from it.

COP_TECH_SUPRT

COP PROVIDED TECHNICAL SUPPORT

Participants described that the co-participants provided technical support while integrating technology tools into their final design project.

Overall it was a new experience for me to create a website. Every time I had any challenges, I took help from my co-participants to solve some of the issues.

INFL_PRIORTCH

INFLUENCE OF PRIOR TEACHING EXPERIENCE

Participants describe how their prior teaching influenced their experience during the professional development program. Include both positive and negative influences.

I felt very difficult in mapping content, pedagogy and technology. This is because I have never taught this subject and I have been developing the concept map just based on my experience as a learner i.e., when I took the course as a student few years back.

INTRSCT_TPACK

INTERSECT TPACK SUB-DOMAINS

Participants describe the process of intersecting knowledge of TPACK sub-domains i.e., content, pedagogy, and technology. Include quotes when participants talk about applying their pedagogical and technological knowledge to the course content.

What I have done in this semester, I have identified the difficult concepts in the start and then identified pedagogic techniques such as taking them to the lab. I haven't done this in the previous semester. I realized that this could be an iterative process.

OUT_CRTQUE

CRITIQUE PRIOR TEACHING EXPERIENCE

Participants reported to critique and identify issues from their prior teaching experience.

In the traditional teaching approach, we treated content, pedagogy and technology as three different things and never tried to effectively connect or compliment them in a way to best help the students achieve the learning outcomes of the course.

OUT_ENDR

TEACHING THROUGH ENDURING OUTCOMES

Participants report to wanting to start teaching their course by introducing students to the enduring outcomes

In the last 2 weeks, I have reflected on this in my classroom and let students know about the enduring outcomes of the course. After every 2-3 days, I am reminding students about the enduring outcomes, so students will always remember the big picture of the course.

OUT_STDNTPER

CONSIDERED STUDENTS' PERSPECTIVES

Participants describe to start taking students perspectives into consideration during their teaching practice.

I realized it is important to take the learners into consideration. I am constantly trying to take feedback from them, identify concepts which might be perceived difficult by the students. This knowledge would help me adapt my instruction accordingly in order to maximize the learning of the students.

OUT_TCHPHL

CHANGE IN TEACHING PHILOSOPHY

Participants describe a change in their teaching philosophy from a teacher-centric to student-centric approach. They reflect on their prior experience and acknowledge it to be teacher centric. Exclude quotes that specifically talk about taking students perspectives into consideration.

Till now we never thought how to teach a subject. We were just teaching, and we never thought if students are learning in the course.

OUT_TECHEFF

INCREASE IN TECHNOLOGY SELF-EFFICACY

Participants report to be confident and excited to continue exploring technology tools to integrate into their courses

I am excited to explore the different tools. I have now decided that as a teacher, I need to keep looking for new tools that can help students to find the course exciting.

SGN_PCK

SIGNIFICANCE OF PCK

Participants describe the importance of developing an understanding of how pedagogy should be adapted based on the course to be become an effective instructor.

To be a good teacher, I need to have a good understanding to how to teach a particular course based on the needs and background of the learners.

SUPRT_EXPLS

PROVIDING EXAMPLES HELPED DURING SESSIONS

Participants described that the examples presented in the professional development sessions helped them in understanding the content

When you use examples that are applicable to my field, it makes it very easy to understand and process the information. That also helps me in making sense of the concepts with respect to the course I am teaching.

SUPRT_PRIORTCH

SUPPORT FROM PRIOR TEACHING EXPERIENCE

Participants described to utilize their prior teaching experience as support resource during the professional development program.

My prior experience helped in identifying which concepts might need videos and which concepts might need a group discussion. Now I know which pedagogy and technology tool I could use based on content in the course.

SUPRT_STDNTS

SUPPORT FROM STUDENTS

Participants described to use students as a support resource and take feedback from them for the final design project

When I developed the course website, I did it by myself in the start. To develop it more effectively, I included students in the process and introduced them to the website. When students starting using it by viewing the content and posting assignments, they provided me with some suggestions on other tools that can be incorporated on the website.

SUPRT_WRKDOC

WORKING DOCUMENT HELPED DURING SESSIONS

Participants described the working document to help them during the professional development sessions

While I was developing the concept map and the working document, I got a lot of clarity on where and how to apply these different pedagogical techniques. The working document helped me individually reason out how to apply the principles and the ICAP framework

TCHAFFR_CONT

REPRESENT CONTENT USING TECHNOLOGY

Participant describe how they could use technology tools to represent content.

We used to make solid modules in the course. We used the modules to teach concepts like front view, top view, side view. The complexity of spatial visualization increases as the course progresses. Now with the website, I can ask students to watch animated videos about the solids before coming to the class. This makes my task of helping students visualize very easy.

TCHAFFR_PDG

TECHNOLOGY TO IMPLEMENT PEDAGOGIC TECHNIQUES
Participants describe how they could use technology tools to implement different pedagogic techniques they planned for their course.
I wanted to implement the flipped classroom methodology in my class. Through Edmodo, I asked students to access the content for certain topics and then engage in discussions in the classroom. This helped in developing the conceptual understanding of students as they were able to solve questions that I provided in the class.

TPACK
DEVELOPING TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE
Participants describe the process of developing the final design project where develop a course website or blog to help students in their learning process. Include quotes where participants talk about how the technology can be used to address limitations of traditional teaching format or the learning needs of the students.
I realized with the course website students can access the resources in my absence. They could see the videos related to the content of the course and that will improve the thinking capability of the students. So, I realized using technology, my job could get easier. Some of the students might not attend all the classroom lectures, and if they miss an important topic, they could use the videos to make up for their absence. I can upload all the course content on a website and give access to the students. So, by using a website I can better support my students learning in the course.

Categories

CAT – Abbreviated name of the category
CATEGORY NAME – Full name of category
CODE - Codes used construct the category

CHALLEN
CHALLENGES
CHALLEN_IDEAGEN, CHALLEN_INTRSCT_TPACK, CHALLEN_TECH, CHALLEN_REF

CM
CONCEPT MAP
CM_CHALLEN, CM_COURSEPLN, CM_INTRSCT_TPACK

COP
COMMUNITY OF PRACTICE

COP_CLRF_MSC, COP_IDEAGEN, COP_KNWLD_EX, COP_TECH_SUPRT

OUT
OUTCOME
OUT_CRTQUE, OUT_ENDR, OUT_STDNTPER, OUT_TCHPHL, OUT_TECHEFF

SUPRT
SUPPORT
SUPRT_EXPLS, SUPRT_PRIORTCH, SUPRT_STDNTS, SUPRT_WRKDOC

TCHAFFR
TECHNOLOGY AFFORDANCE
TCHAFFR_CONT, TCHAFFR_PDG

TPACKDEV
DEVELOPMENT OF TPACK
TPACKDEV_INTRSCT_TPACK, TPACKDEV_TPACK

PUBLICATIONS

Evenhouse, D., Zadoks, A., Freitas, C. C. S. de, Patel, N., Kandakatla, R., Stites, N., DeBoer, J. (2018). Video coding of classroom observations for research and instructional support in an innovative learning environment. *Australasian Journal of Engineering Education*, *0*(0), 1–11. https://doi.org/10.1080/22054952.2018.1519984

R. Kandakatla, J. Ortega, R. Streveler, & K. Smith. (2018). Faculty Apprentice as a Mentorship Model for Engineering Graduate Students interested in Teaching. Paper presented at IEEE Frontiers in Education Conference (FIE).

Y. Duan, R. Kandakatla, N. Stites, J. DeBoer, E. Berger, and J. Rhoads. (2018) The Relationship Between Demographic Characteristics and Engagement in an Undergraduate Engineering Online Forum. Paper presented at IEEE Frontiers in Education Conference (FIE).

Kandakatla, *R.*, Goldenstein, A., Evenhouse, D., Berger, E., Rhoads, J., DeBoer, J. (2017) MEERCat - A Case Study of How Faculty-led Research Initiatives Gave Rise to a Cross-departmental Research Center with Potential to Inform Local Policy. Paper presented at ASEE 2018 Annual Conference.

Zadoks, A., Stites, N. A., Evenhouse, D., Patel, N., Kandakatla, R., Berger, E., Rhoads, J. & DeBoer, J. (2017). Longitudinal analysis of instructor actions in an active, blended, and collaborative classroom environment. IEEE Frontiers in Education Conference (FIE).

Evenhouse, D., Freitas, C., Patel, N., Kandakatla, R., Prebel, T., Stites, N., DeBoer, J., Rhoads, J., Krousgrill, C., Berger, E. (2017). Development of video coding structure to record Active, Blended, and Collaborative pedagogical practice. Paper presented at 7th Research in Engineering Education Symposium (REES).

Evenhouse, D. A., Kandakatla, R. R., Stites, N. A., Patel, N., Zadoks, A., Prebel, T., DeBoer, J. (2017). What does an In-Class Meeting Entail? A Characterization and Assessment of Instructor Actions in an Active, Blended, and Collaborative Classroom. Presented at the 2017 ASEE Annual Conference & Exposition.

In Review

Kandakatla, R., Rhoads, J. F., Berger, E., & DeBoer, J. (2019). Technology-Mediated Resources as a Substitute to Human Resources: Experiences of International Undergraduate Students in an Active, Blended, and Collaborative (ABC) Classroom in the USA. Paper submitted to 8th Research in Engineering Education Symposium (REES).

Kandakatla, R., Rhoads, J. F., Berger, E., & DeBoer, J. (2019). Student Perspectives on the Learning Resources in an Active, Blended, and Collaborative (ABC) Learning Environment in a Core Undergraduate Engineering Course. *Manuscript Submitted for Publication.*

Kandakatla, R., Rhoads, J. F., Berger, E., & DeBoer, J. (2019). The Development of Social Capital in an Active, Blended, and Collaborative Engineering Class. *Manuscript Submitted for Publication.*

In Revisions

Kandakatla, R., Ballesteros, B. Cabrera, J. B., Guerra, D., Rhoads, J. F., Berger, E., & DeBoer, J. (2019). Mixed-Methods Study to Investigate the Adoption and Influence of Evidence-Based

Teaching Practices on Students' Learning in a Core Mechanical Engineering Solid Mechanics Course. *Revisions in progress.*

Freitas, C., Kandakatla, R., Cabrera, J. B., Rhoads, J. F., Berger, E., & DeBoer, J. (2019). A Faculty Perspective on Adopting Active, Blended, and Collaborative Learning in their Mechanical Engineering Course in Colombia. *Revisions in progress.*