CHARACTERIZING MIDDLE GRADE MATHEMATICS TEACHERS' TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) USING A ROBUST DATA SET

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Abstract

Teachers' combined knowledge of contents, technologies, and the pedagogical methods has become a focus of understanding and evaluating teachers' quality. Much of the research uses rubrics to assess technological pedagogical and content knowledge (TPACK) but are limited in that the data sources are oftentimes only lesson plans. The purpose of this study was to characterize mathematics teachers' TPACK using a robust data set that includes the lesson planning process (written lesson plan), implementation of the lesson as represented through video, and teacher reflection about the lesson. Fifteen middle grade mathematics teachers' Technology Lesson Cycles data (the robust data) were assessed and analyzed using a pretested rubric which is the first part of the study. Findings from the study illustrate that the in-service mathematics teachers' pedagogical knowledge (PK) and the knowledge components that contain PK are relatively weaker than other components. Among all seven TPACK components, the technological pedagogical knowledge (TPK) was the weakest knowledge component. This work brought forward a deeper understanding of how TPACK translates to practice. Recommendations were provided for teacher education programs and for future studies.

Keywords: Teacher Knowledge, TPACK, Teacher Education, Technology Integration

Introduction

Theoretical Framework

Incorporating appropriate technologies in mathematics instruction is an expectation across national standards (National Council of Teachers of Mathematics, 2000). Effective teaching with technology requires a developed, nuanced understanding of the complex interplays between three key kinds of knowledge: content knowledge, pedagogical knowledge, and technological knowledge; and how they play out in specific contexts (Mishra & Koehler, 2006). Based on research, a framework commonly used to describe teacher knowledge as it relates to the incorporation of technology is referred to as technological pedagogical and content knowledge (TPACK) (Mishra & Koehler, 2006). Figure 1 illustrates TPACK as the intersection of the three primary forms of knowledge: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technology Knowledge (TK).

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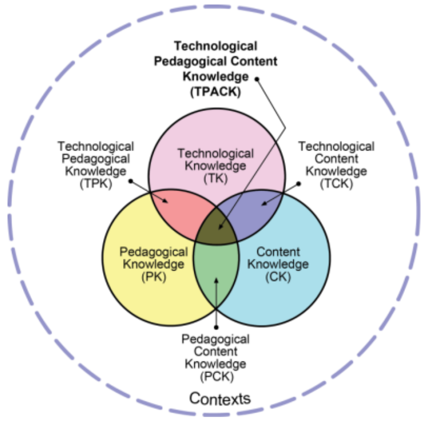
Figure 1
Graphic Representation of Technological Pedagogical Content Knowledge (TPACK)



Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), p. 1025.

This framework allows one to look into teacher's individual knowledge component such as technological pedagogical knowledge (TPK). The individual knowledge component such as TPK demonstrates the ways in which the knowledge of teaching practices combines with the knowledge of technology so that a teacher implements technology in a way that best impacts student learning. When all three knowledge areas are combined, it forms the framework, TPACK, in which teachers' knowledge is combined to produce effective teaching of content utilizing technology in a way that identifies, produces, and enhances student learning (Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2009; Koehler & Mishra, 2006).

Need for the Study

There is a wealth of research related to the use of TPACK as a framework for conceptualizing teachers' knowledge as it relates to pedagogy and technology. Much of the research about TPACK attends to pre-service and practicing teachers' beliefs and attitudes about technology and about self-efficacy beliefs regarding integrating technology in practice. (Archambault & Crippen, 2009; Doering, Scharber, & Miller, 2009; Graham et al., 2009; Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2006; Yurdakul et al., 2012). Since last decade, studies have focused more on how to assess TPACK using teacher created written lesson plans (Harris, Grandgenett, & Hofer, 2010; Kereliuk, Casperson, & Akcaoglu, 2010; Kim et al., 2015). These studies have helped to conceptualize teachers' TPACK, however, they have not included the actual implementation of the lesson. In other words, research centered on the use of teaching practice data which includes multiple components to characterize teachers' TPACK have rarely seeing in the literature.

Purpose of the Study

The purpose of this study was to characterize mathematics teachers' TPACK using written lesson plans, videotaped implementation of the lessons, and teachers' reflections about their lessons. To better understand the middle-grade mathematics teachers' TPACK characteristics, a new method was adopted in this researcher's study. The intent was to use a rubric to analyze lesson cycle data of fifteen middle-grade in-service mathematics teachers to learn how they use TPACK and how the study could infer TPACK from written documents and videos of instruction. Descriptive analysis, observation, and content analysis methods were used to analyze the practicing data of the mathematics teachers who were enrolled in a graduate course about using technology in instructional practices.

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This study used multiple data sources to assess in-service middle-grade mathematics teachers' TPACK, a procedure that has not been often used in the literature. The methodology developed in this study could potentially contribute to the literature for assessing teacher knowledge. The results of this study provided further evidence of how CK and PK, CK and TK, and PK and TK intersect in the TPACK framework described by Mishra and Koehler (2006). Characterizing in-service mathematics teachers' TPACK in practice can potentially expand the understanding of teachers' TPACK and how they use their TPACK in their classrooms. The characterization helps teacher educators in identifying teachers' specific TPACK (CK, PK, TK, PCK, TCK, TPK) levels, leading appropriate professional development programs for specific areas. Findings from a study such as this would also inform teacher educators in designing coursework and professional development regarding educational technology integration in teaching.

Literature Review

Teaching is a complex activity that requires teachers with multiple knowledge areas. Historically, the teachers' knowledge was focused on content knowledge and pedagogical knowledge only. Over the years, greater access to computer technologies has encouraged teachers to develop technology knowledge as well. More recently, the area that has received greater attention is the knowledge construct related to the integration of technology in instruction.

Shulman (1986) introduced a new way of thinking about one aspect of teacher knowledge which he called pedagogical content knowledge (PCK), acknowledging in part how content knowledge and pedagogical knowledge intersect. Based on Shulman's contribution to the field, Mishra and Koehler (2006) developed a framework for thinking about teacher knowledge as it relates to using technology. They called this construct technological pedagogical and content knowledge (TPACK). It represents the complex relationship and intersection of three primary forms of knowledge: Technology Knowledge (TK), Pedagogy Knowledge (PK), and Content Knowledge (CK) (see Figure 1, p. 2). Considerable research has been conducted using the framework of TPACK to conceptualize and to understand teachers' knowledge required for effective teaching and technology integration. This framework has been implemented in many studies to investigate and understand specific learning activities and environments (Abbitt, 2011; Archambault & Crippen, 2009; Doering, Scharber, & Miller, 2009; Graham et al., 2009; Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2006; Yurdakul et al., 2012). The TPACK concept has become a widely used framework in research that focused on understanding teacher knowledge and teaching practice.

Since last decade, scholarship addressing teachers' TPACK has focused increasingly on how this knowledge can be assessed. Several studies developed self-reported survey instruments for reliability and validity of TPACK assessment (Archambault & Crippen, 2009; Niess, M. L., van Zee, E., & Gillow-Wiles, H. 2010-11; Schmidt, Baran, Thompson, Koehler, Shin & Mishra, 2009). Several studies developed performance assessments (Angeli & Valanides, 2009; Groth, Spickler, Bergner & Bardzell, 2009). By 2015, at least ten more validated self-report survey instruments and rubrics had appeared in the literature (Burgoyne, Graham, & Sudweeks, 2010; Chuang & Ho, 2011; Figg & Jaipal, 2011; Landry, 2010; Lee & Tsai, 2010; Lux, 2010; Sahin, 2011; Yurdakul, et al., 2012), including four validated rubrics (Harris, Grandgenett, & Hofer, 2010; Hofer, Grandgenett, Harris & Swan, 2011; Kereluik et al., 2010; Kim et al., 2015) and different types of TPACK-based content analyses that had adequate levels of interrater reliability (Clement et al., 2003; Graham, Borup & Smith, 2012; Hechter & Phyfe, 2010; Koh & Divaharan, 2011; Mouza, 2011; Mouza & Wong, 2009). Researchers believe that because of the complexity of TPACK, scholarship that develops methods for TPACK measurement will probably continue (Harris, Grandgenett, & Hofer, 2010).

Schmidt et al. (2009) designed a TPACK survey instrument for preservice teachers. The instrument constructed contained seventy-five items for measuring preservice teachers' self-assessments of the seven TPACK domains. This instrument measured preservice teachers' self-assessments of the TPACK domains, not their attitudes toward TPACK. Koehler, Mishra, and Yahya (2007) developed a coding protocol related to TPACK analysis and used discourse analysis to track the development of TPACK. They analyzed the conversations of teachers working in design teams, tracking the

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development of each of the seven categories of TPACK over the course of a semester. Their research suggested that this approach only works when applied to specific methodology particular to unique contexts.

There have been studies that focused more on how to assess TPACK using teacher-created, written lesson plans (Harris, Grandgenett, & Hofer, 2010; Kereliuk, Casperson, & Akcaoglu, 2010; Kim et al., 2015). These studies helped to conceptualize teachers' TPACK but did not include the actual implementation of the lesson. In other words, using teacher practice data to characterize teachers' TPACK has not been often utilized. There is a need for characterizing in-service mathematics teachers' TPACK in practice to expand the current understanding of teachers' TPACK and how teachers use their TPACK in the classroom. This need especially includes middle-grade mathematics teachers' TPACK which plays a crucial role in children's learning at this important period in their education. This study examined teachers' TPACK through data that included a lesson plan, videotaped implementation of the lesson, and the teacher's reflection about the lesson. The characterization helps teacher educators identify teachers' TPACK levels, influencing the design of appropriate professional development programs aimed at increasing teachers' knowledge and skills necessary for integrated teaching.

Methodology

Context

The participants of this study were middle-grade mathematics teachers enrolled in an online graduate course, "Teaching Secondary Mathematics with Technology," which was a part of a M.Ed. program for in-service mathematics and science teachers at an urban university located in a south-central region of the United States. The course was designed to promote teachers' development of various TPACK components and was taught for four fall semesters over four years. This study used 15 mathematics teachers' archival data from fall 2012, 2013 and 2014 semesters.

A key assignment of this course was called the *Technology Lesson Cycle*. This assignment required the submission of a detailed, written lesson plan with multiple components. These included an evaluation plan, a brief paper describing research/literature about how the chosen technology supports student learning, evidence of learning outcomes provided by teachers, at least 20 minutes of video-taped instruction of the lesson, and teachers' reflection about the overall lesson. Teachers chose topics and technologies that were available to them at their respective schools and were encouraged to try technologies with which they were unfamiliar.

Data

The *Technology Lesson Cycle* assignment was archived data in Blackboard Learn, the course management system for the course. Teachers submitted the lesson plan, the literature review, and lesson reflection in a Word document. Video was submitted through a hyperlink or mailed to the instructor on a CD or USB stick. At the time of the study, some of the videos of practice were unavailable. For the purpose of this study, only complete Lesson Cycle submissions of mathematics teachers were used for analysis. Fifteen of the thirty-four mathematics teachers' Lesson Cycle submissions were complete and therefore utilized for the purposes of this study.

Rubric Development

A significant part of the methodology in this study was the development of a rubric that was used as a tool to characterize TPACK. Most of the available rubrics in the literature were designed to evaluate a specific task or an assessment, specific to the researchers' study, and therefore were not applicable to this study.

Pilot data were used to develop the rubric. The finalized rubric was tested for reliability. Interrater reliability was examined using Intraclass Correlation (0.734), and internal consistency within the rubric was computed using Cronbach's

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Alpha. The test result was significant ($p = 0.007$, $p < 0.05$). The result of the analysis indicated the rubric was a valued instrument for this study. The rubric is included as Appendix A.

Table 1
Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.734	.713	6

Table 2
Intraclass Correlation Coefficient

	Intraclass	95% Confidence Interval		F Test with True Value 0			
	Correlation[b]	Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.315[a]	.049	.750	3.757	6	30	.007
Average Measures	.734	.237	.947	3.757	6	30	.007

Rubric Application

The fifteen middle-grade mathematics teachers' Technology Lesson Cycle data, which represents how teachers operationalize their TPACK in practice, was applied to the rubric using descriptive and video analysis methods. Each component of the TPACK was characterized as "Weak" "Marginal" "Proficient" and "Strong" based on the analysis. Descriptive, observation, video and content analysis methods were used to analyze the mathematics teachers' complex data during the process. Lesson plans provided the general sequence of the lessons, including the lesson objective, technologies to be used, engagements and students' activities, and evaluation plans. The technology research papers provided evidence of what the teachers knew about technologies that impact classroom teaching and the rationale of why they chose the particular technologies included in the lesson. The video data was used to capture lesson content and classroom events, and to determine if the teachers' plans were implemented in the actual instruction. Teacher reflections about their lessons provided evidence of teachers' abilities to learn to adapt to new technologies and to show the ways in which teachers' understandings of the content can be changed by the application of technologies.

Results

The results were organized in a TPACK characterization pattern chart and the percentages of each scale character—from weak to strong—for all teachers combined are listed in Table 3.

Table 3
The Percentage of Scale Character of the TPACK

TPACK Scale	Technological Pedagogical and Content Knowledge						
	CK	PK	TK	TCK	PCK	TPK	TPACK
Weak	0%	0%	0%	0%	0%	0%	0%
Marginal	0%	0%	0%	0%	7%	27%	13%
Proficient	0%	40%	7%	20%	33%	33%	40%
Strong	100%	60%	93%	80%	60%	40%	47%

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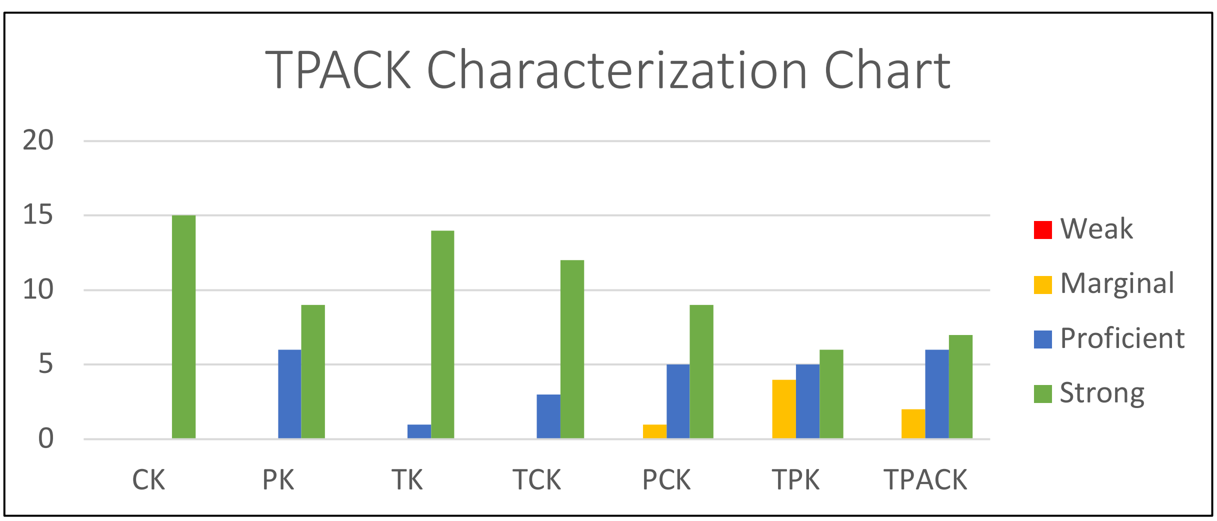
Characterization Results

The results were based on the analysis of each of the fifteen mathematics teachers' data that consisted of written lesson plans, technology research papers, video of lesson implementation, and teachers' written reflections about the lessons. Based on the data analysis, all teachers demonstrated strong content knowledge (CK). The data indicated that teachers had the ability to apply procedures accurately, efficiently, and flexibly. The teachers also showed strong understanding of concepts being taught and were able to use them strategically to solve problems. All teachers exhibited proficient mathematical language ability, using it strategically and frequently. Most of their lesson plans were carefully planned and included detailed information about engagement and activities, the content objectives, and the technologies used. In addition, most of their lesson plans were consistent with the implementation of their lessons. Sixty percent (60%) of teachers were characterized as strong in pedagogical knowledge (PK) and 40% were characterized as proficient. Ninety-three percent (93%) were strong and 7% were proficient in technology knowledge (TK). Eighty percent (80%) were strong and 20% were proficient in technological content knowledge (TCK). In regard to pedagogical content knowledge (PCK), sixty percent (60%) were characterized as strong, 33% were characterized as proficient, and 7% were characterized as marginal. For technological pedagogical knowledge (TPK), forty percent (40%) were strong, 33% were proficient, and 27% were marginal. Finally, in the area of technological pedagogical and content knowledge (TPACK), 47% of teachers were characterized as strong, 40% were as proficient, and 13% were as marginal.

Discussion

When looking at individual components separately (Figure 2 and Table 3), the teachers as a group demonstrated strong knowledge in three basic knowledge components of the TPACK. These were content knowledge (CK), technology knowledge (TK), and pedagogical knowledge (PK). The teachers' combined PK, however, was somewhat more proficient and less strong than the other two components. Another significant pattern that emerged in the chart analysis was that the teachers' knowledge strength decreased on three of the four combined knowledge components—pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), and the combination of the three components of their technological pedagogical and content knowledge (TPACK). The teachers' TPK demonstrated the most marginal and least strong levels among all components (Table 3 and Figure 2). Their technological content knowledge (TCK) was relatively the strongest among the combined knowledge components, with 80% of teachers rated strong and 20% proficient. The teachers' strong TCK was constant with their strong CK and TK.

Figure 2
TPACK Characterization Chart



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Summary Comments

Results of the study provided detailed characteristics of these fifteen mathematics teachers' knowledge. They appeared to have solid knowledge of CK, PK, and TK according to the analysis. Consistently, the CK, PK, and TK formed relatively weaker knowledge characteristics when combining these three knowledge components. These results provided further evidence of how CK and PK, CK and TK, and PK and TK intersect in the TPACK framework described by Mishra and Koehler (2006). Although the teachers' three single knowledge components were strong, the teachers' knowledge characteristics were weakened when these single knowledge components intersected with each other. Results also indicated that the PCK, TPK, and TPACK associated with PK demonstrated relatively weaker knowledge characteristics than TCK, which did not include the PK component. Additionally, this result further emphasized the importance of, and the difficulties in, acquiring pedagogical knowledge which requires an understanding of cognitive, social, and developmental theories of learning and how they apply to students in their classroom (Mishra, & Koehler, 2006; Shulman, 1986).

The rubric developed in this study demonstrated validity reliability in analyzing the practicing data and evaluation of teachers' TPACK levels. The TPACK characterization chart promoted the effective organization of the data analysis results. The findings helped to answer the guiding question of this study which was: In what ways can we characterize middle school mathematics teachers' TPACK? Utilizing a specific rubric that was developed using pilot data to analyze teachers' comprehensive practicing data (i.e., lesson cycle which represented how teachers operationalized their TPACK in practice) facilitated the characterization and understanding of the middle school in-service mathematics teachers' TPACK by characterizing each component into weak, marginal, proficient, and strong levels.

Recommendations

Several recommendations emerged from this study regarding teacher training, rubric development, and future research.

Teacher Training

One of the important findings in this study was that teachers' TPK proved to be the weakest component of all seven TPACK components. This finding could be used to inform the design of course work for pre-service and in-service teachers. Findings also suggested the need for teacher education or professional development programs to increase the focus on developing mathematics teachers' TPK, or more specifically, the strategies to engage and to guide students in using technologies to explore and learn content. In addition, the development of PK needs to be a continuous priority in teacher education programs. The results of this study suggested that mathematics teachers' lower PK could be one of the factors keeping other combined knowledge components (including TPACK) at a weaker level. It was not surprising, however, that PK, the knowledge of teaching strategies, was shown to be a difficult knowledge to acquire. For these reasons, those knowledge components of teachers' TPACK that contain PK (i.e., PCK, TPK, and TPACK) should be greatly emphasized when providing trainings for both pre- and in-service teachers. This supports a recommendation to reevaluate teaching methods courses for both university and alternative certification program (ACP) undergraduate students in order to improve pre-service teachers' PK that may affect other knowledge components of their TPACK.

Rubric Development

In regard to the rubric developed and utilized in this study, it is recommended that the rubric be further tested to improve its usability, reliability, and validity. For example, the interrater reliability of the rubric could be improved to its optimum level by further examining the rating descriptions of the rubric in order to more accurately characterize the different components of teacher knowledge. Additional testing of the rubric (applying the rubric to new sets of participants) would also improve rubric reliability and validity, and perhaps indicate modifications needed.

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Further Research

There are also several recommendations related to future research, the first of which deals with data quantity and collection. For the purpose of this study, only complete Lesson Cycle submissions data was used for analysis. The more Technology Lesson Cycle submission data can be used for analysis, the more precise pattern of teachers' TPACK characteristics may be generated.

For the next step, in-service mathematics teachers' TPK needs to be further studied to understand what makes this particular component weaker than CK, PK, TK, TCK, PCK, and TPACK. Further studies would potentially provide additional recommendations for what needs to be done to improve teachers' TPK, as well as other components of TPACK in general.

Limitations of the Study

In order to fully evaluate the relevance and impact of this study's findings, the limitations of the study were fully explored in regard to data, impact, and design. The first point considered regarding data was that the participants were a unique group of teachers enrolled in an online graduate course for the M.Ed. degree at the university. Since the data was used for a course grade (which could have contained potential sources of bias and exaggeration), the data may not have reflected the teachers' true ability or TPACK level. Another limitation was the use of archival data in regard to teacher interviews in that it prohibited this researcher's ability to conduct direct interviews with teachers which may have yielded a deeper understanding of their experiences in designing and implementing technology-integrated mathematics lessons.

There was also a possible impact limitation since all teachers in this study were middle-grade teachers. For this reason, the results may not have been applicable to all in-service mathematics teachers across grade levels from elementary to senior high school. Finally, although the rubric developed for this study reached an adequate level of the interrater reliability, it did not reach the optimum level 80% that is recommended by Clement et al. (2003) and by Harris, Grandgenett, and Hofer (2010), it demonstrated an internal consistency of 73.4% which is above the adequate level of 70%, according to Donner and Wells (1986). This result may have affected accurate data analysis.

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Appendix A
Rubric Use to Analyze Mathematics Teachers' TPACK in Practice
(CUIN 6346 Lesson Cycle Assignment)

Teacher name: ____ Grade level: __________________________
Class: ____ Lesson: ______________________________

Data sources: The written lesson; teacher reflections about the lesson; evidence of learning outcomes provided by the teacher; video of implementation

TPACK Components	Criteria	Category (1 Weak – 4 Strong)					Overall Rating (circle one)
		1	2	3	4	Score	
Content Knowledge (CK)	A) Procedural understanding of content	Apply procedures poorly, or inefficiently;	Ability to apply procedures somewhat accurately and efficiently,	Proficient in applying procedures accurately and efficiently; transfer procedures to different problems and contexts	Strong ability to apply procedures accurately, efficiently, and flexibly; transfer procedures to different problems and contexts		**Weak** (111;121) (1 – 1.5) **Marginal** (122; 222; 223) (1.5 – 2.5) **Proficient** (233; 333; 334) (2.5 – 3.5) **Strong** (344; 444) (3.5 – 4)
	B) Conceptual understanding of content	Lack of ability to understand concepts being taught and encounter difficulties when use them to solve problems	Understanding concepts being taught and able to use them to solve problems with difficulty	Understanding concepts being taught and able to use them strategically to solve problems	Strong understanding of concepts being taught and able use them strategically to solve problems; strong ability to identify misconceptions		
	C) Mathematical languages	Minimum or no mathematical language	Appropriate use of mathematical language	Sufficient mathematical language and use them appropriately and frequently	Strong mathematical language ability and use the language strategically and frequently		
Pedagogical Knowledge (PK)	A) Appropriate assessments	Assessments are less or not relevant to the concepts being taught and do not reflect teachers' understanding of students' cognitive abilities	Assessments are somewhat relevant to the concepts being taught and they may not reflect teachers' understanding of students' cognitive abilities	Assessments are relevant to the concepts being taught and reflect teachers' understanding of students' cognitive abilities	Assessments are relevant to the concepts being taught in full extent and reflect teachers' strong understanding of students' cognitive abilities		**Weak** (111;121) (1 – 1.5) **Marginal** (122; 222; 223) (1.5 – 2.5) **Proficient** (233; 333; 334) (2.5 – 3.5) **Strong** (344; 444) (3.5 – 4)
	B) Organize and manage student behavior	Teachers are less or not able to use rules, procedures to engage students learning; students' misbehavior are ignored	Teachers are somewhat able to use rules, procedures to engage students learning; students' misbehavior sometimes are ignored	Teachers are able to use rules, procedures to engage students learning; students' misbehavior are corrected in a timely manner	Teachers use rules, procedures, and routines to ensure that students are actively involved in learning; students' misbehavior are prevented		
	C) Class activities reflect an understanding of developmental theory of learning and how students learn	Learning activities are less or not appropriate to students' cognitive abilities and students are having hard time in learning	Learning activities are somewhat appropriate to students' cognitive abilities and students are learning in someway	Learning activities are appropriate to students' cognitive abilities and students are engaged in learning	Learning activities are appropriate to students' cognitive abilities and students are actively engaged in learning		

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TPACK Components	Criteria	Category (1 Weak – 4 Strong)					Overall Rating (circle one)
		1	2	3	4	Score	
Technological Knowledge (TK)	A) Knowledge of the technology application	Teachers have less or no knowledge of the technology application used in teaching	Teachers somewhat understand the technology application used in teaching	Teachers have a sufficient knowledge of the technology application used in teaching	Teachers understand the technology application used in teaching proficiently		**Weak** (111;121) (1 – 1.5) **Marginal** (122; 222; 223) (1.5 – 2.5) **Proficient** (233; 333; 334) (2.5 – 3.5) **Strong** (344; 444) (3.5 – 4)
	B) Knowledge of operating particular technologies	Teachers are not able to use the technology application appropriately	Teachers are able to use the technology application with some degrees of difficulties	Teachers are able to use the technology application appropriately	Teachers are able to manipulate and use the technology application strategically		
	C) The ability to learn and adapt to new technology	Teachers show less or no ability to learn and adapt new technology and are not able to find solution when encounter technology issues	Teachers show somewhat ability to learn and adapt new technology and able to find solution with difficulty when encounter technology issues	Teachers show proficient ability to learn and adapt new technology and able to find solution when encounter technology issues	Teachers show strong ability to learn and adapt new technology and able to find solution quickly when encounter technology issues		
Technological Content Knowledge (TCK)	A) Link between technology and content is obvious or explicit	The technology choice not properly suits to contents and students may not be learning content objectives	The technology somewhat links to contents and it can be used in some ways to teach contents	The technology choice suits contents and it can be used to teach contents	The technology choice best address contents and it can be used in a variety of ways in teaching contents		**Weak** (111;121) (1 – 1.5) **Marginal** (122; 222; 223) (1.5 – 2.5) **Proficient** (233; 333; 334) (2.5 – 3.5) **Strong** (344; 444) (3.5 – 4)
	B) An understanding of the representation of concepts using technologies	Teachers have less or no ability to use technology representations to help students to understand the concept	Teachers somewhat have the ability to use technology representations to help students to understand the concept	Teachers have the ability to use technology representations to help students to understand the concept	Teachers have strong ability to use technology representations to teach contents and understand the effect of tech on the concept		
	C) An understanding of the content can be changed by the application of technology	Teachers are not able to use the same technology to link between different contents or concepts	Teachers are somewhat able to use the same technology to link between different contents or concepts rarely provide examples	Teachers are able to use the same technology to link between different contents or concepts and provide examples	Teachers have a strong ability to use same technology to link between different contents or concepts and able to teach and provide examples of different contents		
Pedagogical Content Knowledge (PCK)	A) Demonstrates awareness of possible student misconceptions	Teachers hardly recognize student misconceptions	Teachers recognize student misconceptions and correct them when they occur	Teachers use casual questions and post questions to uncover misconceptions and able to lead to conceptual change	Teachers use casual questions and post questions to uncover misconceptions strategically and promote continual positive conceptual change		**Weak** (111;121) (1 – 1.5) **Marginal** (122; 222; 223) (1.5 – 2.5) **Proficient** (233; 333; 334) (2.5 – 3.5) **Strong** (344; 444) (3.5 – 4)
	B) Knowing how elements of the content can be arranged for better teaching	Teachers have less or no understanding of rearranging contents for better teaching	Teachers have some understanding of contents can be rearrange for better teaching	Teachers are able to rearrange the contents necessary based on class progress, students' cognitive ability, and their prior knowledge	Teachers have strong ability to rearrange the contents necessary based on class progress, students' cognitive ability, and their prior knowledge effectively		

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TPACK Components	Criteria	Category (1 Weak – 4 Strong) 1	2	3	4	Score	Overall Rating (circle one)
	C) Knowledge of teaching strategies that incorporate appropriate conceptual representations of the content in order to guide student thinking and learning, and address learner difficulties and misconceptions.	Teachers have less or no ability to use effective teaching strategy such as using manipulative to guide student thinking and learning, and address learner difficulty and misconnections	Teachers have somewhat ability to use effective teaching strategy such as using manipulative to guide student thinking and learning, and address learner difficulty and misconnections	Teachers are able to use effective teaching strategy such as using manipulative to engage and guide student thinking and learning, and address learner difficulty and misconnections	Teachers have strong ability to use effective teaching strategy such as using manipulative or pictorial representations to engage and guide student thinking and learning, address learner difficulty and misconnections		
Technological Pedagogical Knowledge (TPK)	A) Evidence of appropriate technologies enhancing student learning. Students use technology to explore content and achieve learning goals	Teachers have less or no ability to use strategies to engage and guide students explore and learning contents with technology	Teachers somewhat able to use strategies to engage and guide students explore and learning contents with technology	Teachers are able to use strategies to engage and guide students explore and learning contents with technology	Teachers have strong ability to use strategies to engage and guide students explore and learning contents with technology		**Weak** (111;121) (1 – 1.5) **Marginal** (122; 222; 223) (1.5 – 2.5) **Proficient** (233; 333; 334) (2.5 – 3.5) **Strong** (344; 444) (3.5 – 4)
	B) Knowledge of how technologies can be used to build on existing knowledge and to develop new ones or strengthen old ones.	Teachers do not demonstrate understanding of using appropriate sequence of technology applications and pedagogical methods to help students to learn new knowledge based on existing ones	Teachers have somewhat ability of using appropriate sequence of technology applications and pedagogical methods to help students to build new knowledge based on existing ones	Teachers demonstrate understanding of using appropriate sequence of technology applications and pedagogical methods to help students to learn new knowledge based on existing ones	Teachers have strong ability of effectively using appropriate sequence of technology applications and pedagogical methods to help students to build new knowledge based on existing ones		
	C) Knowledge of pedagogical strategies and the ability to apply those strategies for use of technologies	Teachers have less or no ability to use technology with appropriate pedagogical strategy in teaching	Teachers are somewhat able to use technology with appropriate pedagogical strategy in teaching	Teachers are able to use technology with appropriate pedagogical strategy in teaching	Teachers demonstrate strong ability to use technology with appropriate pedagogical strategy in teaching		

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TPACK Components	Criteria	Category (1 Weak – 4 Strong)					Overall Rating (circle one)
		1	2	3	4	Score	
Technological Pedagogical and Content Knowledge (TPACK)	A) Appropriate technology enhances content objectives and instructional strategies	Teachers are not able to use appropriate technology enhance contents with appropriate teaching strategies	Teachers have somewhat ability to use appropriate technology enhances contents with appropriate teaching strategies	Teachers are able to use appropriate technology enhance contents with appropriate teaching strategies	Teachers demonstrate strong ability to use appropriate technology enhance contents with effective teaching strategies		**Weak** (111;121) (1 – 1.5) **Marginal** (122; 222; 223) (1.5 – 2.5) **Proficient** (233; 333; 334) (2.5 – 3.5) **Strong** (344; 444) (3.5 – 4)
	B) Demonstrate the knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face	Teachers have less or no knowledge of what makes concepts difficult or easy to learn and how technology can help	Teachers somewhat demonstrate knowledge of what makes concepts difficult or easy to learn and how technology can help	Teachers demonstrate knowledge of what makes concepts difficult or easy to learn and how technology can help	Teachers demonstrate strong knowledge of what makes concepts difficult or easy to learn and how technology can help		
	C) Pedagogical techniques that use technologies in constructive ways to teach content	Teachers are not able to use pedagogical techniques that use technology in constructive ways to teach contents	Teachers are somewhat able to use pedagogical techniques that use technology in constructive ways to teach contents	Teachers are able to use pedagogical techniques that use technology in constructive ways to teach contents	Teachers demonstrate strong ability of using pedagogical techniques that use technology in constructive ways to teach contents		

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