

Original Research Article

Preservice teachers' technological, pedagogical and content knowledge in utilizing the Merrill's first principles in solving polynomials

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Abstract

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This study paper examined preservice teachers' technological, pedagogical and content knowledge (TPACK) in utilizing the Merrill's First Principles to solve problems in polynomial equations in order to showcase its relevance in modern technological discourse. Quasi-experimental and mixed exploratory sequential designs were adopted on 25 preservice teachers in the Department of Basic Education, University of Education, Winneba in Ghana. The data collection instruments consisted of 12 open-ended items in the knowledge and applications of the computer in using polynomial equations. Thematic analysis as well as single-subject t-test hypothesis revealed the low base of technological pedagogical and content knowledge of preservice teachers in solving polynomial problems. There is therefore the need to vigorously champion curriculum design principles that are sacrosanct with technology integration in the teaching and learning of mathematics in basic schools.

Keywords: Merrill's First Principles, Polynomials, Preservice Teachers, TPACK

INTRODUCTION

There are various instructional designs have critical implications in determining what, why, and how mathematical instructions should be structured and followed in the classroom. Given the significance attached to students' learning and achievements in examinations, new paradigms of instructional designs require serious analysis, consideration, and reflection on not only the delivery but also the impact of the learning new instructional design models that provide clear information on how the intended learners should learn and develops in tandem with the society and community they belong to. In achieving this goal, four general good instructional goals--clarity, practice, feedback, and motivation should be embossed. First, clarity considers what should be mastered, and the specific performance(s) the learner must demonstrate. Second, practice considers learners' opportunities and skills being learned. Third, feedback calls for corrective strategies of the concepts learned. Fourth, motivation attain entails

both intrinsic and extrinsic satisfaction after learning concepts (Reigeluth, 1999; Huitt, Monetti and Hummel, 2009; Waiyakoon, Khlaisang and Koraneekij 2015).

In order to achieve these goals, a good instructional design should be able to evaluate and redirect learners' knowledge and understanding. There are three qualities of evaluation to analyse how well that instructional design works. These are effectiveness, efficiency, and appeal. Effectiveness requires that appropriate indicators of learning be identified so as to objectively measure the learning goals. Efficiency requires an optimal use of resources (human, time and money) to obtain the desired goals. Level of appeal describes the degree to which learners enjoy the instruction, especially proponents of child-centered approaches. It is believed that no single design can successfully achieve all these goals. Therefore, exploring preservice teachers' technological, pedagogical and content knowledge (TPACK) in utilizing the Merrill's First Principles in named concepts (solving

polynomials) foster teaching and learning (Reigeluth, 1999; Huitt, Monetti and Hummel, 2009; Burrell and Cohn 2012).

Koehler, Mishra, and Cain (2013) have formulated approaches aimed at developing preservice and inservice teachers' TPACK. Two of these are Pedagogical Content Knowledge (PK), and Technological Pedagogical Knowledge (TPK), which have built on preservice and inservice teachers' prior knowledge and experiences with the core computer knowledge. The TPACK centres experiences with defining, designing, and refining instructional goals to solve particular learning problems. Harris, Mishra and Koehler (2009) have extended the TPACK framework not only to teaching, learning, and integrating technology, and but also encouraging the professional development of TPACK-based designs and accommodating flexible and inclusive philosophies, strategies and approaches that enlighten, encourage and guide preservice and inservice teachers to select designs that attain the four goals.

Agyei and Voogt (2011), Agyei (2013), and Agyei (2015) have identified and utilized ICT tools in the mathematics classroom in a variety of ways. Some of these tools are portables, graphic calculators and other computerized application software. In particular, they discovered that the use of graphic calculators and computerized graphing speeds up work, encourages problem solving skills, and builds relationships in mathematics concepts.

Theoretical framework of Merrill first principles

Merrill First Principles are fundamental invariant principles of good instructional design that does not rigidly follow a particular theoretical framework. However, it is centrally constructivist, demands activities of learners to achieve the goals, and applied as instructional and as evaluation of pedagogical (Merrill, 2006). Constructivism is based on the fact that learners actively explore their environment by building on their existing cognitive structures, called schemas. When these schemas are adequate to deal with a new situation or problem, learning is said to have occurred by the process of assimilation. But when an existing schema is not adequate enough to deal with the new situation or problem, a process of accommodation is required whereby learners modify their existing schemas. In the latter, constructivism builds on learners' current knowledge, and motivate them through the process of accommodation to make progress to solve challenging problems. Even though critiques suggest that constructivism is context-specific and elitist, its theoretical framework holistically encompasses the cultural, environmental and social experiences of learners (Dubinsky, 1997; Westbrook, et. al., 2013).

Model of the Merrill's First Principle

The Merrill's conceptual model in Figure 1 begins with the problem where learning is facilitated when learners are engaged in solving real-world problems, when learners are shown the task that they will be able to do or the problem they will be able to solve as a result of completing a module or course, when learners are engaged at the problem or task level not just the operation or action level, and when learners solve a progression of problems that are explicitly compared to one another. The problem phase seeks to explore whether the instructional design involves authentic real-world problems or tasks to mirror the interaction, contextualize the problem-solving processes, focus training on thinking processes, and incorporate specific problem-solving processes. The problem also addresses the issues of whether the instructional design direct learners the whole task they would solve as a result of applying the instructional design that provides clear (to the learner) and complete procedural processes on solving the problem, applying instructional goals that narrow what students focus on, applying instructional goals that goal-oriented and not topic-oriented, and instructional design that always embed with short statement of goals (Rosenshine, 1997; Merrill, 1997, 2001; 2002).

In addition, the problem addresses the instructional components of the tasks to guide the learner to use these components in solving the whole problem in order to guide learners practice the parts of processes in the context of the overall process and present new material in small steps (Rosenshine, 1997; Marzano, Pickering and Pollock, 2001). And in breaking the problem into pieces, the instructional design should involve a progression of the problems and not just a single application (Merrill, 2007).

The models progress to the activation of relevant previous experience, where pupils learn by recalling, relating, describing, or applying knowledge, initiating new knowledge, and demonstrating previously acquired knowledge or skill. Closely following this is the demonstration. The Activation phase explore the ability of the instructional design to guide to recall, relate, describe and apply prior knowledge from relevant past experiences that lays solid foundation for the new knowledge. The instructional design should provide relevant and effective cues and questions to produce deeper learning, to activate relevant pre-existing knowledge, to develop background knowledge and to review relevant previous learning that serves as prerequisite skills and knowledge for the new learning. The instructional design should also confidence in their ability to acquire the knowledge and skills in order to help learners to become actively engaged in by clearly communicating the utility of the goals, assure learners that their effort will pay off in terms of enhanced

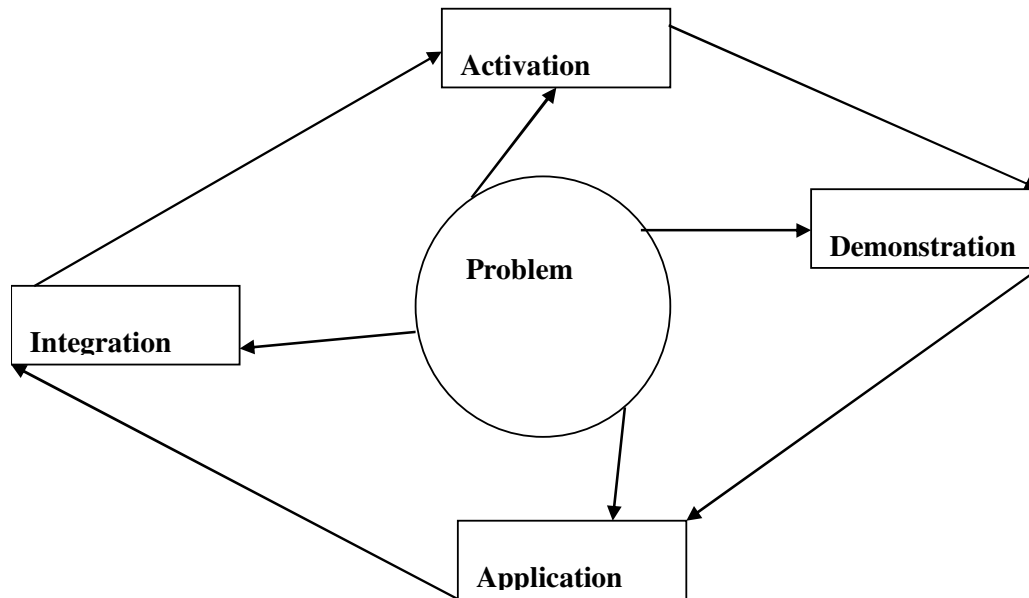


Figure 1. Structure of Merrill's First Principle Model (Merrill, 2006)

achievement and encourage learners to personalize the goals (Merrill, 1997; 2001; 2002).

In addition, the instructional design should encourage the recall of a structure that can be used to organize the new knowledge to guide learners to represent similarities and differences of knowledge, to summarize explicitly the structure of the information, to generate non-linguistic systems of representation, to organize important real information, to provide learners with conceptual models that facilitate the acquisition of problem-solving skills, to provide semantic mappings to help learners acquire the interrelationships of a knowledge domain, and to provide and teach a checklist (Merrill, 2007).

The demonstration phase is the current ongoing knowledge through simulations, visualizations, and modelling by different representations, consistent examples with the content, directed reading, multiple representations and multiple demonstrations, and relevant media content. This phase explores on an instructional design that demonstrate what is to be learned rather than merely telling information about what is to be learned to guide learners to practice the problems with worked examples, to exemplified the teaching and concepts, principles, and problem-solving procedures, to explain new concepts, concepts, principles, and problem-solving procedures, and to classify many different relevant concepts, concepts, principles, and problem-solving procedures that are required to enhance learning. The demonstration activates misconceptions and errors that misdirect learning, to provide opportunity for learners to scaffold to reflect the learner's prior knowledge and conceptual elaboration, to visualize the outcomes of the processes, to make clear narrative description integrated with the visual models of the

sequences, to provide statements about the causes and effects, and to guide the processes gradually to more novel and complex knowledge (Merrill, 1997; 2001; 2002).

Also, the demonstration should direct learners' attention to relevant information on the key steps in order to present learners with explicit guidance in identifying similarities and differences, to foster learners' independent identification of similarities, to signal the negative and positive effects of the information, and to improve upon visual representations of complex texts to map words to graphics. The demonstration guides learners to relate the new information to the conceptual structures, to enlighten their problem-solving processes, to generate and test hypotheses, to condition learners to pre-existing knowledge, and provide clear and detailed instructions and explanations on the processes (Merrill, 2007).

The third phase is the application. Application is the art and science of exhibiting demonstrated knowledge through problem-solving tasks and using multiple distinctive types of Merrill practice (information-about, parts-of, kinds-of, and how-to). This phase explores on how learners are provided with opportunity to practice and apply their newly acquired knowledge and skills in order to acquire critical tasks in the environment, to provide high level of active practice in the field, and to check for learners' understanding. This ensures that the practice and assessments are consistent with the stated and implied goals of the curriculum to ensure that practice require learners to recognize information, to describe part and whole of the knowledge, to identify new examples of each kind, and to apply taught concepts to new challenging scenarios (Merrill, 1997; 2001; 2002).

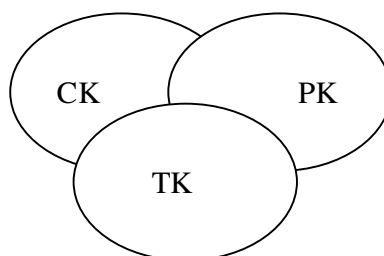


Figure 2. TPACK Framework (Harris, Mishra and Koehler, 2009)

Also, application shows corrective feedback and an indication of progress in ensure effective learning progress, to administer corrective feedback, to provide superior performance on later tests, and provide systematic feedback and corrections. The practice enables learners to access context sensitive in solving the problem in order to provide procedural prompts, to provide models of appropriate responses, to anticipate and discuss potential difficulties, and to regulate the difficulties of the tools. The practice should support learners' cognitive strategies, increase their response-abilities and delve into new knowledge and skills to solve varied sequences of problems in a variety of structured tasks (Merrill, 2007).

After application comes the integration of instruction, reflection, discussion, sharing, collaborative work and community learning to integrate (transfer) the new knowledge, to publicly showcase the new knowledge, to reflect-on, discuss and defend new knowledge, and to create, invent, or explore new and personal ways to use new knowledge. The Integration phase explores how the instructional design provides techniques that encourage learners to integrate and transfer the new knowledge and skills into their everyday life. The instructional design should provide an opportunity for learners to publicly demonstrate their new knowledge and skills, provide opportunities for learners to reflect, discuss, and defend their new knowledge and skills. This would deepen their understanding of the principles they are applying. The design should also provide opportunities for learners to create, invent, or explore new and personal ways to use their new knowledge and skills. This would ensure that society reaps the benefits of investments into the teaching and learning processes ((Merrill, 1997; 2001; 2002; 2007).

Even though we used the Merrill's First Principles to evaluate the tasks, there are other instructional designs that could also be explored with the technological, pedagogical and content knowledge, namely Dick and Carey, Morrison/Ross/Kemp, Beeson, General Military, 4C/ID, ADDIE in 3-D, CRESST, Felder design, Phoebe pedagogic planner and Wiki-supported project-oriented learning models. However, the Merrill's First Principles are simple to conceptualize with technology, easy to

integrate with any themes and faster to apply in the classroom situation (Merrill, 1997; 2001; 2002).

Technological, Pedagogical and Content Knowledge (TPACK)

The new educational paradigms require new knowledge and understanding that utilizes technology into the teaching and learning of mathematics. Therefore, preservice and inservice teachers' computer skills and competencies are essential in the quest for teaching mathematics for integration. TPACK model identifies the specific knowledge and understanding needed to learn how to integrate instructional designs. Accordingly, adequate utilisation and integration of technology in teaching requires a type of teacher education and training that is based on varied competencies and skills to ensure effective methodology for the implementation of pedagogical strategies.

It also requires a design where teachers' knowledge can be redefined to interact for the sole purpose of dealing with the new teaching and learning strategies. The TPACK model integrates content knowledge (CK), technological knowledge (TK) and pedagogical knowledge (PK) with the core aim of equipping preservice teachers to integrate computers into the teaching and learning processes of mathematics (Mishra and Koehler, 2006; Harris, Mishra and Koehler, 2009; Gera and Verma, 2012; Koehler, Mishra and Cain, 2013).

The Figure 2 represents the TPACK framework we adopt for the integrative model. The T, C, and P represent technological, content and pedagogical knowledge respectively. It is worthy of note that the Technological Knowledge or TK represent knowledge about all sorts of technology and computers, Content Knowledge or CK represent knowledge about the subject matter, and Pedagogical Knowledge or PK represent knowledge about teaching and learning methods and processes, classroom management and organisation, curricular analysis and planning). Also, the Pedagogical Content Knowledge or PCK represent content knowledge associated with the teaching-learning process, and integrating of content and pedagogy, the Technological

Content Knowledge or TCK represent knowledge of technology in creating new learning models, and Technological Pedagogical Knowledge or TPK represent knowledge of technological tools used in teaching and learning. The combination of all the knowledge domains makes up the TPACK.

TPACK is the knowledge required for preservice teachers and in-service teachers to utilize and integrate computers into the teaching and learning activities and processes of any mathematics content. Therefore, an effective utilization and integration of computers into the Merrill's First Principle requires knowledge and understanding of this TPACK model in the course of teacher education and training (Mishra and Koehler, 2006; Doukakis et al., 2010; Jang and Chen, 2010; Graham, 2011; Pamuk, 2012; Srisawasdi, 2012; Chai, Koh, and Tsai, 2013; Koehler, Mishra and Cain, 2013; Koehler, Mishra, Akcaoglu, and Rosenberg, 2013; Maeng, Mulvey, Smetana and Bell, 2013; Voogt et al., 2013; Mouza et al., 2014).

Conceptual Framework of Merrill's Principles and TPACK

In order to effectively utilize and integrate computers into the education and training of teachers, we adopted conceptual the frameworks in Merrill's Principles and TPACK models to help build relationships between technology and content so that preservice teachers acquire the professional knowledge and skills in technology that supports the learning of mathematics content. This ensures that preservice teachers should not only acquire specific pedagogies in educational designs but also specific pedagogies that facilitate learning of content with technology. For instance, we situated our study in the teaching and learning of polynomials because the concepts in polynomials are holistic and interdisciplinary with computer, pedagogies (Agyei and Voogt, 2011; Doukakis, et al., 2010; Agyei and Voogt, 2012).

We opine that computer technology has weaknesses and strengths, regardless of the method teacher educators select to develop and train preservice teachers with TPACK models. However, the planning, implementation and development of any TPACK model in the classroom began with relatively familiar and simple computers, such as laptops and calculators, and gradually progress to more advanced (Koehler and Mishra, 2008; Koehler et al., 2011). Particularly, in the case of pre-service teachers in Ghana, where Agyei (2015) identified the limited knowledge and skills in TPACK and its constituent parts, it is important for teacher educators and policy makers to adopt our models. Additionally, preservice teachers should be provided ample opportunities to encounter relevant mathematics problems that support and call for TPACK

models to achieve teaching and learning goals (Koehler, et al., 2013). In that case, preservice teachers would discover that utilization of computer technology is not separate from content and pedagogy, since teacher educators and curriculum designers need the content area specialisation to model TPACK and the pedagogy in order to present content (Herring et al., 2014).

Merrill's Principles and TPACK Integration in Mathematics

Mathematics continues to be a major tool of applications of technology on the development of content and the evolution of instruction. Technology also impacts on the development and expansion of new and existing mathematical knowledge, skills, concepts and applications. Technology has afforded mathematics to apply computer algorithms in order to create, analyze, and define conceptual structures. Similarly, mathematics has influenced computer content, development and exploration in areas such as statistics, algebra, probability, geometry, matrices and solutions to polynomials (Lee et al., 2006; Guerrero, 2010).

Again, electronic calculators and computers are essential tools for teaching, learning, and assessment in mathematics. These tools allow visualization of mathematical ideas, organization of teaching and learning procedures, and computations of problems efficiently and accurately. The main visuals are mathematical models, objects, figures, diagrams, and graphs. These visuals bridge the gaps between concrete and abstract conceptual structures. Equally, these technology tools focus on decision making, reflection, reasoning, and problem solving skills to foster deep conceptual understanding over rote procedural skills (Guerrero, 2010; Benning and Agyei, 2016).

There are five general approaches that dominate technology integration. These are software-focused initiatives; demonstrations of sample resources, lessons, and projects; technology-based educational reform efforts; structured and standardized professional development workshops/courses; and technology-focused teacher education and training courses. Software-focused initiatives integrate areas of mathematical learning with and general problem-solving skills the use of the programming language. Demonstrations of sample resources, lessons and projects often demand classroom-based and student-tested appropriate technology use to provide a wide range of sources (such as magazines, books, Web sites, and conference presentations) to customize them to fit their particular contexts. Technology-based educational reform efforts bring larger-scale and often grant-funded projects that are geared towards organizing new visions for learning and teaching through systemic planning and intensive professional development efforts. Structured

and standardized professional development workshops or courses are large-scale professional development initiatives that are pre-structured options and adopted locally to offer the pre-packaged professional development to teachers. Technology-focused teacher education courses are fashioned around teacher education institutions and authorities that offer educational technology courses to teachers through either online or face-to-face delivery (Lee, et. al., 2006; Guerrero, 2010).

Though different from each other, these approaches tend to initiate and organize their efforts according to the educational technologies being used and do not address learners' needs relative to curriculum-based content standards. These approaches are inadequate, comparatively weak and in our model of integration (Agyei, 2015).

Our five-phase Merrill's' Principles were utilized by the TPACK framework in identifying mathematical problems that desire computers, activating learners to cultivate positive attitudes towards computers, demonstrating the processes with computers in polynomials, applying knowledge and understanding with computers, and making decisions on how to integrate teaching and learning mathematics with computers. The framework did not only utilize computers but also demonstrated their abilities, willingness and mental fortitude to adopt TPACK in simple curriculum designs for teaching and learning of Mathematics ((Lee, et. al., 2006; Sorto and Lesser, 2009; Guerrero, 2010).

The first problem is that in most modern teaching and learning classroom settings for preservice teachers, where classroom sizes are so large and preservice teachers are expected to transfer new knowledge, skills and attitudes from the teacher training situations and apply in their classrooms, interdisciplinary and integrative designs that focus on computer technology are understandingly necessary. Studies show that the calculator and the computer encourage analytical thinking and the capacity of preservice and inservice teachers to apply knowledge in solving practical problems (Center for the Study of Mathematics Curriculum, 2010; Tennyson, 2010). However, preservice teachers overlook, misplace and inadequately address the essence of TPACK (Agyei and Voogt, 2012; Agyei and Voogt, 2014). It is therefore, prudent to begin with the simple five-phase Merrill's First Principles with TPACK in teacher education and training, and graduate this basic design with 4C/ID, ADDIE in 3-D, CRESST, Felder design, Phoebe pedagogic planner and Wiki-supported project-oriented designs (Merrill, 1997; 2001; 2002). This would help deep and effective TPACK hat motivate learners, and ease the transferring and utilization of the knowledge to everyday life.

Many studies have been conducted on integrated TPACK frameworks for in-service and pre-service teachers' employing either qualitative or quantitative of both qualitative and quantitative methods (Lee, et. al.,

2006; Doukakis, et. al., 2010; Agyei, 2015; Benning and Agyei, 2016). However, not much has been explored and utilized with a named instructional design in solving problems in mathematics. Our quest to adopt the Merrill's Principles was o ensure that preservice teachers acquire the knowledge and understanding of the various stages of lesson delivery, and to enhance technology use in each of the phases.

The study sought to explore the following issues:

1. What Merrill's' Principle(s) do preservice teachers mostly utilize in solving problems in polynomials?

2. Null Hypothesis: The scores of preservice teachers were not significant 5% level of significance.

Alternative Hypothesis: The scores of preservice teachers were significance at 5% level.

MATERIALS AND METHODS

The methodology was largely mixed sequential exploratory approach. The researchers framed themes from the five Merrill's Principles, qualitatively analyzed the preservice teachers' responses, and followed the responses by quantitative t-test single-subject analysis to explain the qualitative responses. In setting the items, twelve open-ended items were distributed to 25 preservice teachers to explore their knowledge and skills in teaching, learning and solving problems in polynomials with computers that encompass the Merrill's five principles. At each phase, we utilized simple computers in solving the problems, collecting the data and analysing the results (Schneider, 2014; Soto, 2013). The table 1 below shows how the main activities involved in each phase were measured by the TPACK (Lee, et. al., 2006; Koehler, Mishra, and Cain, 2013).

The thematic framework provided the exploratory knowledge and skills of the TPACK levels preservice teachers utilized in solving the polynomial problems. The levels of utilization in each TPACK were ranked as either excellent, very good, good, average or below average and discussed. The single-subject t-test was required describe and evaluate the statistical significance of the preservice teachers' knowledge and skills in the five principles of the model (Lee, et. al., 2006; Koehler, Mishra, and Cain, 2013; Agyei, 2015; Benning and Agyei, 2016).

RESULTS AND DISCUSSION

Table 2 shows how the preservice teachers TPACK competencies and skills in the Merrill's principles. As observed from the Table 2, the preservice teachers had very high PCK, TCK, TPK and ultimately TPACK in the problem phase of the Merrill's principles in solving the polynomials. At this phase, all components of TPACK framework were appropriately displayed due to the fact

Table 1. Framework of Merrill's First Principles Measured with TPACK

Merrill's Principles	Main Activities	TPACK Measured
Problem	Describe the problems computers can be used for	Identifying the mathematics problems computer can be used to solve polynomials
Activation	Describe the activations through explanations inbuilt functions the computers have.	Exploiting inbuilt mathematical functions in computers to solve polynomial functions
Demonstration	Describe the demonstration through explanations of algorithms in the computers.	Demonstrating mathematical knowledge and skills in using computers to solve polynomial problems
Application	Describe the applications through explanations of mathematical problems the computers can be used for.	Applying and utilizing knowledge and skills in computer programming to solve polynomial problems
Integration	Describe the integrations through explanations of areas the computers can be used for.	Extending and utilizing knowledge and skills to encourage stakeholders to adopt computers in solving mathematics programs

Source: (Sorto and Lesser, 2009; Appleby, et. al., 2014)

Table 2. Merrill's First Principles and Measures of TPACK Framework

Principle/Knowledge	Pedagogical Content Knowledge	Technological Content Knowledge	Technological Pedagogical Knowledge	Technological Pedagogical Content Knowledge	Overall Principle
Problem	Very high	Very high	Very high	Very high	Very high
Activation	Very high	Good	Good	Good	Good
Demonstration	Good	Moderate	Moderate	Moderate	Moderate
Application	Moderate	Low	Low	Low	Low
Integration	Low	Poor	Poor	Poor	Poor
Overall Knowledge	Good	Moderate	Moderate	Moderate	Moderate

that the preservice teachers recognized, conceptualized and solved the problems well. One can therefore conclude that the preservice teachers could interpret the content of polynomials, find alternative ways to solve problems and adapt the computer tool to enhance pedagogy.

According to the Table 2, the preservice teachers had very high PCK, but good TCK, TPK and TPACK in the activation phase. This means the preservice teachers advanced very good pedagogical arguments and skills in activating the computer tools but lacked the requisite competencies and skills to apply the TCK, TPK and TPACK in solving the problems. For instance, while the preservice teachers could solve the problems in polynomials, it was not uncommon to observe them list wrong polynomial functions as statistics, matrix equations and vectors. This was attributed to the availability and familiarity of mathematical strategies and methods but absence of computer skills and competencies (Koehler and Mishra, 2008).

The responses also show that the preservice teachers had good PCK, but moderate TCK, TPK and TPACK in the demonstration phase. This means the preservice teachers clearly proved good pedagogical skills and competencies in demonstrating how the computer tools should be used to solve the problems but lacked the appropriate algorithms to apply the TCK, TPK and TPACK in solving the given problems. For instance, most

preservice teachers could solve the linear, quadratic and cubic problems with the computers but failed to demonstrate the algorithms involved in solving any one type of the polynomials.

In addition, the preservice teachers had moderate PCK, but low TCK, TPK and TPACK in the application phase. This means the preservice teachers clearly applied the appropriate algorithms given to solve the various polynomial problems but lacked the appropriate technical skills and competencies to set their own problems and programme their own basic algorithms to solve the problems. In the items involving this phase, most preservice teachers could solve the linear, quadratic and cubic problems with the computers but failed to apply their knowledge to provide steps and illustrate the steps in solving any one type of the polynomials.

Worst still, the preservice teachers had low PCK, but poor TCK, TPK and TPACK in the integration phase. This means the preservice teachers minimally integrated pedagogical skills and competencies in infusing how the computer tools to solve the problems but lacked the appropriate knowledge to integrate the TCK, TPK and TPACK in solving social and community problems. For instance, while most preservice teachers could assign reason for and merits of integrating computers into every facet of life, almost all of them failed to pinpoint any particular areas where computer skills and competencies could be integrated.

Table 3. T-Test Single Subject Analysis

Polynomials	Test Values = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval	
					Lower	Upper
Linear equations	6.095	24	0.001	2.160	1.43	2.89
Quadratic equations	6.195	24	0.001	1.480	0.99	1.97
Cubic equations	7.135	24	0.001	2.440	1.73	3.15
Three linear equations	39.852	24	0.001	4.760	4.51	5.01

Finally, the preservice teachers had overall moderate TPACK. This means that the preservice teachers were unaware of the intersection between content, pedagogy and technology, which forms the basis upon which technology utilization and integration could be successful. This therefore, required concerted efforts by teacher educators and experienced teachers to emphasize not only on the strategies and methods of solving mathematics problems but also apply and integrate TCK and TPK methodologies in teacher education and training. This would enhance technological use in classroom teaching and learning and to design and solve lower levels mathematics problems with computer but also to extend and integrate higher order problems into mathematics teaching and learning.

The results in table 3 show the single-subject t-test to provide the within-subjects t-test statistics and compare the means of the polynomial functions. The major statistics in the table are t-statistic, degrees of freedom, two-tailed p-values and confidence intervals at 95%. The one-tailed test showed that the performance in the four polynomial functions significantly different from zero. Thus, single-subject t-tests were all significant: ($t(25) = 6.095$, $p = 0.001$) for two system of linear constructs, ($t(25) = 6.195$, $p = 0.001$) for quadratic constructs, ($t(25) = 7.135$, $p = 0.001$) for cubic constructs, and ($t(25) = 39.852$, $p = 0.001$) for three systems of linear constructs.

Implications for Policy Making

We have observed the unique and varied interactions between technology, pedagogy, and content in our quest to utilize and integrate teaching and learning with the Merrill's First Principles. Due to the high interdependences among pedagogy, content and technology, preservice teachers face a number of challenges in conceptualizing and contextualizing the interplay of three dimensions of TPACK in solving problems in polynomials. The diversity of the various responses implies that teacher educators and experienced serving teachers should be transformative in designing mathematics curriculum to reflect the Merrill's Principles.

It is also worthy of note that the complex and structured nature of the TPACK framework call for curriculum designers to vigorously champion the TPACK design and constantly liaise the processes of problem solving and computational strategies with the Merrill's First Principles. As noted by Koehler, et. al. (2013), the onus lies in the curriculum designer to finding the problems, discovering the solutions, making sense out of the solutions, and reframing the problems. This is the only way to imbibe Merrill's Principles into TPACK in developing world, where their curricula lack computer integration (Agyei, 2015).

All curricula comprise of cohesive collection of teaching and learning strategies, teaching and learning resources, teacher-learner interactions, and extra-curricula activities. The design of any curriculum model is bound to fail if utilizing and integration are ignored, abandoned and isolated. These interrelated segments and resources are only brought together by TPACK frameworks. Preservice teachers are regarded as the early birds that catch the worm, and should actively experience the integration process to provide solid foundations for TPACK revolution (Koehler et al. 2013).

CONCLUSION

First, the findings of the TPACK framework were comprehensive and holistic to all teaching, learning, and technology integration. The findings revealed that that TPACK-based teacher education and training accommodate all curriculum designs and approaches, theoretical and conceptual frameworks, philosophical and instructional views, and teaching and learning methodologies. It is very flexible and inclusive to only Merrill's First Principles but other adjoining curriculum designs. Also, the study afforded the preservice teachers opportunities to explore and apply the efficacy of TPACK-based education and training models to maximize their cognitive capabilities, creativity and professional adequately. But for this study, many preservice teachers never discovered the powers of simple calculators and computers in solving problems in mathematics. In addition, the findings revealed how new educational designs are inevitable and change with time. However,

effective TPACK framework ensures effective teaching and learning by constantly updating and revising curriculum contents and contexts to contextualize and interlace new technology, pedagogy, and content. In confronting technology, content, and pedagogy with the Merrill's First Principles in interactive classroom contexts, the findings demonstrated how the preservice teachers aggressively and actively participated in the sessions of the data collection exercises. The TPACK framework provided preservice teachers the motivation and strengths to consider applying design principles to technology integration in solving mathematics problems.

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