Comparing pre-service teachers' PCK through 9E instructional practice: case of Mathematics and Technology pre-service teachers

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Abstract

Instructional practice plays a significant role in understanding teachers' pedagogical content knowledge (PCK). The aim of this study is to compare mathematics and technology pre-service teachers' knowledge of PCK. This study used a case study approach of five mathematics and five technology pre-service teachers with a total of ten. Data was collected in seven public schools around Gauteng province in South Africa. The observation technique was employed in order to understand students' classroom practice using a video camera to capture the setting. One lesson of 45-minutes presented by each pre-service teacher, making a total of ten lessons, was observed. The study adapted the theoretical framework of PCK (Shulman, 1987). The study scrutinized the data based on the qualitative content analysis method and found that most pre-service teachers in both mathematics and technology possess a limited knowledge of PCK. In both subjects, most of the pre-service teachers' classroom practice did not exhibit comprehensive knowledge of the subject matter or knowledge of the learners. However, the difference is that only mathematics pre-service teachers have some knowledge of assessment. The data also indicate that "9E" instructional practice can be a valuable tool to enhance field specific PCK within the field of mathematics and technology education subjects. Therefore, this study proposes further investigation of the "9E" instructional model that could be used as field specific (FS) PCK within the fields of mathematics, science and technology.

Key words: pedagogical content knowledge, field specific PCK, knowledge of subject matter, knowledge of students; knowledge of assessment

Introduction

Instructional practices are like vehicles; they are used by teachers to efficiently move students forward in their learning. Consequently, for PCK to be realized in teachers, teaching effective instructional practice needs to be established. Pedagogical content knowledge (PCK) is a complex endeavour that requires teachers to meld content knowledge, pedagogical strategies and knowledge about the nature of how learners learn (Marshall & Sorto, 2012), According to Shulman (1987), PCK is the amalgamation of content and pedagogic knowledge that is uniquely the province of teachers and their own special form of professional understanding. Correspondingly, Lee and Luft (2008) pointed out that PCK can be divided into three categories: general PCK, domain-specific PCK and topic-specific PCK. For example, in the science field, general PCK is related to science as a subject; domain-specific PCK is connected to different domains within science, such as chemistry, biology, Earth science, and physics; and topic-specific PCK is relevant to a list of concepts, terms and topics in science.

On the same footing, Eilks and Byers (2010) have argued that PCK is domain specific knowledge, which means it is not readily transferable. Hence, in recent years an increasing variety of research has been done in teachers' PCK in different fields, for example, science (Eilks & Byers, 2010; Mavhunga & Rollnick, 2013), biology (Park & Chen, 2012; Jüttner et al., 2013), mathematics (Depaepe, Verschaffel, & Kelchtermans, 2013; Petrou & Goulding, 2011); and technology (Khoza, 2013; Rohaan, Taconis & Jochems, 2012). Based on its application within many related subjects, this study argues that PCK can be field specific. However, its instructional practice to establish uniformity and transferability within those fields is imperative.

Research Questions

The aim of this study is to compare the PCK of mathematics and technology pre-service teachers.

1. Which knowledge of PCK do mathematics and technology pre-service teachers possess?
2. Can the 9E instructional model be used as a criterion to evaluate the PCK of pre-service teachers?
3. Can the 9E instructional model be transferred to other related fields as FSPCK?

Studies in Technology Education PCK

Although there is a growing body of analytic clarification and empirical research with regard to PCK, especially with a focus on fields such as Science, Mathematics and Life Science, few attempts have been made to learn more about teachers' PCK in Technology Education (TE), especially in the South African context. For example, Khoza (2013) conducted a study to investigate student teachers' difficulties when doing sectional drawings in engineering and graphics design. The study observed the teaching and learning of sectional drawing and used PCK to analyse teachers' practice. The study found that lecturers' ways of facilitating sectional drawing create difficulties for students in learning this concept. However, considerable research has been conducted in countries such as New Zealand on PCK in technology education. For example, Rohaan, Taconis and Jochems (2012) analyzed primary teachers' knowledge in New Zealand focusing on subject matter knowledge, pedagogical content knowledge, attitude, and self-efficacy through tests and questionnaires. The study found that subject matter knowledge is an important prerequisite for both pedagogical content knowledge and self-efficacy. Research in PCK for TE teaching should be conducted despite the rich research findings in other subjects such as Science (Park & Oliver, 2008; Rollnick et al., 2008) and Mathematics (Depaepe et al., 2013). These findings are not applicable to PCK for TE teaching because PCK is specific to the content of a specific subject. Therefore, this study seeks to investigate pre-service teachers' knowledge of technology, which includes both CK and PCK.

Studies in Mathematics Education PCK

A number of studies have been conducted in PCK in the field of mathematics education globally. Many studies have been conducted in mathematics focusing on various aims and purposes rather than on assessing the PCK of pre-service teachers and have especially focused on classroom activities. For example, most studies have focused on the following areas: understanding how pre-service teachers construct teacher knowledge and pedagogical content knowledge of elementary mathematics (Lowery, 2002); reviewing the way in which PCK was conceptualized and (empirically) studied in mathematics education research (Depaepe et al., 2013); conceptualising teachers' mathematical knowledge for teaching (Petrou & Goulding, 2011); conceptualising and measuring teachers' topic-specific knowledge of students (Hill et al., 2008); exploring mathematical knowledge for teaching and the mathematical quality of instruction (Hill et al., 2008); developing measures of teachers' mathematical knowledge for teaching (Hill et al., 2004); exploring the effects of teachers' mathematical knowledge for teaching on student achievement (Hill et al., 2005); and, identifying mathematical knowledge for teaching (Ball et al., 2008).

Despite the number of investigations in mathematics, the need to further investigate its practice in different contexts should not be concluded. In support of this view, Baumert et al. (2010) indicated that in the United States and Europe, concerns have been raised on whether pre-service and in-service training succeeds in equipping teachers with the professional knowledge they need to deliver consistently high-quality instruction. Therefore, this study intends to observe the PCK of pre-service teachers through their instructional practice in order to explore the effectiveness of university curricula in preparing them to teach the school curricula.

PCK

This study adapted the theoretical framework of PCK from Shulman (1978) to assess pre-service teachers' knowledge in their classroom practice. To assess the PCK of pre-service teachers in their classroom teaching, this study proposed the 9E instructional model as a measure to evaluate classroom instructional activities. As stated above, pedagogical content knowledge is a special amalgamation of content and pedagogy that falls uniquely in the province of teachers, and is their own special form of professional understanding (Shulman, 1987, p. 8). It includes understanding how a particular topic is taught and encompasses the manner in which problems or issues are organised, presented and adapted to the diverse interests and abilities of learners. Since the inception of PCK, an increasing number of researchers have worked on this concept (e.g. Grossman 1990; Magnusson, Krajcik & Borko 1999; Van Driel, Verloop & de Vos, 1998).

Grossman (1990) identified six components of PCK for science teaching, i.e. knowledge of students' understanding; knowledge of curriculum; knowledge of instructional strategies; knowledge of assessments of students; learning of subject matter; and orientation to teaching subject matter. Based upon the work of Grossman (1990), Magnusson et al. (1999) adapted the existing framework of PCK and identified five discrete components, namely (i) orientation towards science teaching, (ii) knowledge and beliefs about the science curriculum, (iii) knowledge of students' understanding of science, (iv) knowledge of assessment in science, and (v) knowledge of instructional strategies. Based on the fact that PCK includes knowledge of subject matter, assessment and how students learn in the classroom (Marshall & Sorto, 2012), this study used the framework of PCK. As a result, this study has adapted the position taken by Grossman (1990) and identified four knowledge domains, as follows: knowledge of subject matter; knowledge of students; knowledge of instructional strategies; and knowledge of assessment.

In order to assess these four knowledge domains in the classroom, this study proposes the 9E instructional model that attempts to reflect significant activities that need to be executed in the classroom in order to assess the PCK of pre-service teachers. According to Hill, Schilling & Ball (2004); Hill, Rowan, & Ball (2005); Ball et al. (2008), throughout the development of PCK most of the studies focused on making general claims about teacher knowledge, teacher education, or policy rather than providing claims about how ideas can be presented in one subject area and how it can be related to those in another subject area. In addition, "even whether findings within the same subject take similar or different views of teacher subject matter knowledge" (Ball et al., 2008:3).

To disguise the gap, Ball and colleagues provided a very good framework of content knowledge for teaching to evaluate teachers' knowledge. During their study they identify five i.e. **Common Content Knowledge (CCK)** which looks at teachers' knowledge of the material they teach; recognizing students wrong answers or when the textbook gives an inaccurate definition (p.399); **Specialized Content Knowledge (SCK)** which looks at presenting mathematical ideas, responding to students' "why" questions, linking representations to underlying ideas, connecting a topic being taught to topics from prior or future years, and selecting representations; **Knowledge of Content and Students (KCS) which looks at** anticipating what students are likely to think, what they will find confusing, choosing interesting and motivating examples, anticipate what students are likely to do with the task, anticipate students will find task easy or hard, be able to hear and interpret students' emerging and incomplete thinking based on the use language; **Knowledge of Content and Teaching (KCT)** which looks at sequencing particular content for instruction, choice of which examples to start with, which examples to use to take students deeper into the content, instructional methods for representing a specific idea or topic. However, the framework did not clearly show how those criteria can be executed.

Though, Ball et al., (2008) criteria shed a light in further developing criteria or how various activities could be executed in the classroom in order to blend CK and PK knowledge. Based on the fact that this study seek to evaluate pre-service teachers practice in the classroom, this study proposed 9E instructional model because it provides clear criteria and further show various modes that can be used to accomplish such criteria. Therefore, this study has found this model relevant to capture pre-service PCK because it focuses on how learners learn and is based on a constructivist approach (Niss, 2012).

9E Instructional Model

The E instructional model is the model that can be used to investigate how knowledge is constructed in classroom practice (Eisenkraft, 2003). Eisenkraft (2003) expanded the 7E instructional model from the 5E instructional model developed by BSCS (Bybee, 1997). The expanded 7E instructional model proposed seven categories, namely, engagement, exploration, explanation, elaboration, elicit phase, expanded and evaluation phase. The present study proposes the additional categories of **exchange phase** and **enlightening phase** and also uses the term enclosure instead of extend. The term, enclosure, was considered suitable in this study because in this context the application of new knowledge to practice is viewed as the conclusion phase of the lesson presentation.

The categories are explained as follows: **elicit** involves prompting the learners' prior knowledge. For example, a pre-service teacher could use different modes like classroom-interaction, pre-assessment, and multimedia strategies to assess learners' prior knowledge. The **elaboration** phase involves the connection of everyday experience/knowledge with a new concept. For example, pre-service teachers could use learners' previous knowledge, personal experience, or local knowledge to build their understanding of the new concept. The **explanation** phase involves continuous explanation of different concepts to enhance learners' understanding. For example, pre-service teachers can use different modes, such as argumentative, justification, descriptive or interpretive to explain different concepts that could be correct or incorrect. **Exploration** involves the accurate introduction of new concepts, processes or skills in a coherent manner to eliminate confusion. For example, pre-service teachers could use different modes like conceptual connection, procedural connection or equivalent representation to present new concepts. The **evaluation** phase involves continuous assessment to evaluate learners' learning which must take place during all interactions with students in all presentation phases. For example, pre-service teachers can use different evaluation modes like a practical task, a concept-focused task or lesson outcome evaluation task to assess learners' understanding of different concepts.

The **enclosure** phase involves the summary of the concepts. A pre-service teacher could use various modes like wrap-up, nutshell, or a continuous summary to conclude the lesson. The **enlightening** phase involves the use of topic-specific strategies that are relevant to the topic. For example, pre-service teachers might use different strategies, like a graphic representation, visual representation, object demonstration, statistic representation and simulation methods to teach different concepts. The **engagement** phase is the continuous involvement of learners throughout the lesson as active participants, which helps them to develop conceptual understanding. For example, pre-service teachers can use different modes like provoking questions, problem-based methods, demonstration or discussion methods to stimulate learners' curiosity, interest and attention. The **exchange** phase involves the use of learners' ideas to identify a teachable moment. For example, pre-service teachers can use learners' responses to build understanding of different concepts and also to correct learners' misconceptions. As indicated earlier, the study adapted four components of PCK for science teaching that are relevant in the classroom. Table 1 below shows how each area of knowledge relates to each E instructional model.

Table 1: Incorporation of 9E Instructional model into PCK

Knowledge of subject matter	Knowledge of Student	Knowledge of instructional strategies	Knowledge of assessment
Elaboration	Elicit	Enlightening	Evaluation
Explanation	Engagement		
Exploration	Exchange		
Enclosure			

Methodology

This study used the comparative case study approach of five (5) technology and five (5) mathematics pre-service teachers. Both technology and mathematics pre-service teachers were selected from a cohort of 4th-year degree students at a university of technology in South Africa. The reason for choosing this group of students is that they are in their final year of study, they have had sufficient classroom experience throughout their studies and because they are in their final year of academic study they are in a position to provide valuable information, views and suggestions without fear. These two subjects were chosen because technology pre-service teachers also take Mathematics as their course subject. Data was collected in six (6) public schools around Gauteng province.

Participants

In technology there were five female i.e. Tefu and Tinny who were teaching at Tsako-thabo high school and Tina, Teddy and Chedza were teaching at Rhulani high school. All pre-service teachers in technology focused on the topic of the lever in grade 8. In mathematics there were three male and two female. Mpho was a female, doing her teaching practice at Hebron Technical School teaching trigonometry functions in grade 10. Mummy was a female, doing her teaching practice at Soshanguve Technical School teaching data handling in grade 9. Melvin was a male, doing his teaching practice at Atteridgeville secondary school teaching geometry in grade 10. Malala was a male, doing his teaching practice at Rhulani Secondary teaching financial growth and decay in grade 9. Mash was a male, doing his teaching practice at Reetumetsi secondary school teaching statistics in grade 10.

Data collection and analyses

The observation technique was employed in order to understand pre-service teachers' classroom practice (Creswell, 2013). One lesson for each pre-service teacher, with a total of 10 lessons, was observed. Each lesson was captured using a video camera for 45 minutes. For confidential purpose the researcher used pseudonymous to identify participants. All ten (10) participants were observed, in order to understand their practice. The study scrutinized the topics based on the qualitative content analysis method (Elo & Kyngäs, 2008), which focuses on the subject and context, and emphasizes the differences between and the similarities within. To analyse data, firstly the researcher watched the video and manually transcribed data into narrative stories. Secondly, the researchers looked at the 9E instructional categories and their explanation, identified and match those categories with the data. Lastly, relevant classroom interactions for each participants were matched with the relevant category in the 9E. In order to verify pre-service teachers' awareness of the 9E categories, the researcher used students' lesson evaluation criteria to identify 9E instructional categories. However, in the lesson-evaluation criteria the 9E instructional model was not explicitly specified, but the points are identified as part of the criteria. The lesson-plan evaluation criteria are used at the university where these pre-service teachers are trained. This evaluation sheet is used in their 2nd and 3rd year practicum evaluation. Therefore, students are familiar with its requirements.

Findings

As indicated earlier, the study used an expanded 9E model to compare the PCK of mathematics and technology pre-service teachers.

Knowledge of Subject Matter

Elaboration phase

The **elaboration** phase involves the connection of everyday experience/knowledge with a new concept. Four (4) of the pre-service teachers were able to incorporate real-life example into their lessons. They used local examples to explain different concepts. For example, for most of the time Tefu used real-life objects like a wheelbarrow to demonstrate the first-class lever, a nutcracker to demonstrate the second class lever and a fishing rod for the third class lever. On the other hand, only one mathematics pre-service teacher was able to connect real-life example into his lesson. The other four (4) pre-service teachers were unable to execute the elaboration phase. This could be because most of the teachers found it difficult to identify real-life example that can explain some of the mathematics concepts.

Explanation phase

This phase involves explanation of concepts in different ways to enhance learners' understanding. The five (5) pre-service technology teachers explained concepts in different ways to help leaners to understand. In doing this the pre-service teachers used descriptive and interpretive methods. However, they showed some misconceptions in some of the explanation they gave. For example, Tefu said: "Let's say I am pushing a wheelbarrow. As I am pushing, the moment I am holding, the more my elbow bends thus my fulcrum". Tefu misrepresented the fulcrum; in technology subject, a human being is considered as something that brings force rather than acts as a fulcrum, however, in other fields, for example, life science her explanation may is be seem correct.

Similarly, all the five (5) mathematics pre-service teachers were able to explain most of the terminology correctly but they ignored the terminologies that they were not familiar with. For example, Mpho mostly used the interpretive mode. Melvin used descriptive, argumentative, and justification explanations to explain different concepts. Also, like the technology pre-service teachers, they ignored the terminologies that they were not familiar with.

Exploration phase

This phase involves accurate introduction of new concepts, processes or skills in a coherent manner to eliminate confusion. The five (5) pre-service teachers were not able to coherently introduce new concepts. They were unable to connect concepts in a procedural manner. For example, Tefu and Tinny could not link the new concept with pre-knowledge. They could not show or explain the connections between concepts. For example, Tina's failed to explain the concepts of lever, load and effort at the beginning of the lesson. She was also unable to explain the link between the concept of "mechanical advantage" and levers and indicate how and why they are calculated; her failure to do these could be due to lack of skill to introduce new concept.

Similarly, all five (5) pre-service teachers did not coherently introduce new concepts. They did not link different ideas or concepts. They were unable to use a procedural connection to link pre-knowledge with new knowledge, to link their lesson with a real-life context, or to link ideas in their lesson from the beginning to the end so that it had a logical flow. For example, Mummy in her lesson introduction defined the three ratios but did link the three ratios. She stated that "those three ratios define three sides which are hypotenuse, opposite and adjacent; the hypotenuse is the longest side because it is long, and the three ratios are defined by three sides". She should have started by identifying and explaining the three sides of a right-angled triangle and then show how three ratios can be calculated using the three sides identified in the right- angled triangle.

Enclosure phase

In terms of summary of the concepts, only two (2) technology pre-service teachers summarised their lessons. They used the continuous summary and wrap-up methods. For example, Tefu used continuous summary to summarise different stages of concepts. She summarised each class of lever before continuing to the next class of lever. For instance, she asked: "Do we understand now?" and repeated: "We said first that the fulcrum is between the load and the effort. Now we are saying that in class two the load is between the fulcrum and the effort". Before she continued with the third class lever she first summarised the first class lever and second class lever. In mathematics, only Melvin continuously summarised each stage before moving to the next stage. By contrast, the other four (4) pre-service teachers were unable to execute the enclosure phase. As a result, Melvin was the only pre-service teacher who concluded his lesson.

Knowledge of Instructional Strategies

Enlightening phase

Three of the pre-service teachers used different methods to explain different concepts. They used the object demonstration method, graphic representation, and visual representation method to explain different concepts. For example, Tefu used a wheelbarrow to demonstrate the first-class lever; a see-saw to demonstrate the second-class lever and a fishing rod to demonstrate the third-class lever. Similarly, three mathematics pre-service teachers used different methods to explain different concepts. They used statistical method, graphic representation and visual representation methods. For example, Mpho used the statistical representation method to teach the concept of the stem and leaf diagram.

Knowledge of Student

Elicit Phase

Elicit involves prompting the learners' prior knowledge.

All five (5) technology pre-service teachers revealed that they are incapable of introducing a lesson. They started all their lessons by seeking a definition of the topic. They could not link their new knowledge with the learners previous lesson or previous knowledge. All five (5) mathematics pre-service teachers were unable to introduce their lesson properly. They did not establish the content knowledge that had been taught in the previous grade or previous lesson. They introduced only new knowledge without understanding the learners' level of pre-knowledge. Although they had an opportunity to use a familiar concept, they were unable to recognise this teaching moment (Mhlolo, 2012). This practice is in contrast with McCormick's (2004:21) argument that knowledge is embedded in a context and not in abstractions, as people do not perceive problems in abstract ways but relate them to whatever they are doing in the current situation.

Engagement phase

Engagement phase is about continuous involvement of learners as active participants in the lesson. Four pre-service teachers were unable to execute the engagement phase. They did not ask thought provoking questions that could engage the learners in discussions. When they attempted asking questions, the questions they asked were of low cognitive demand like what is a lever. They were not able to engage the learners in a discourse. In mathematics only two pre-service teachers involved learners their lesson presentation. For example, Melvin involved learners by using the teacher-led and learner-led demonstration method. He used the question-and-answer method and allowed learners to come to the front to write their responses and gave opportunity to the leaners to critique each other's solutions.

Exchange phase

At this phase the teacher uses learners' ideas to identify a teachable moment. Chedza was the only pre-service teacher who used the learners' ideas and responses to questions as an instance to teach. For example, one learner responded that the example of a shell is a "stone" and the other one said that it was a "rock". She told them that "a stone and rock are the same thing". She also showed an interest in the learners' responses while she was correcting a learner who said that a nest is an example of a shell. After the learner had said that, Chedza asked the class the following: "A nest is an example of what?" She also explained to them why their answer was incorrect. In contrast, the other four pre-service teachers did not use leaners responses and ideas as an opportunity to teach during their lessons. They did not have time to correct learners who answered incorrectly and appeared to lack interest in those who did not raise their hands because they knew that they would give the wrong answer. When learners gave wrong answers the teachers did not probe further into the learners' ideas but responded by answering the questions themselves.

In mathematics, Mummy used the learners' responses to questions and ideas as an opportunity to teach. She gave learners the opportunity to write their solutions on the chalkboard and through probing into the students ideas provided opportunity to for the learners to learn. In contrast, the other four pre-service teachers did not use the learners' ideas and responses to questions as an instance to teach. For example, Melvin did not engage with the responses that were incorrect but was interested only in the correct answers..

Knowledge of Assessment

Evaluation Phase

All the technology pre-service teachers did not give class activities to the leaners during the lesson to assess their leaning. They only asked question but did not give class activities during. In contrast, all the mathematics pre-service teachers gave learners class activities to formally evaluate their learning during the lesson.

Discussion and Conclusion

The aim of this study is to compare mathematics and technology pre-service teachers' knowledge of PCK. Figure 1 below reflects pre-service teachers' dominant categories of the 9E instructional model.

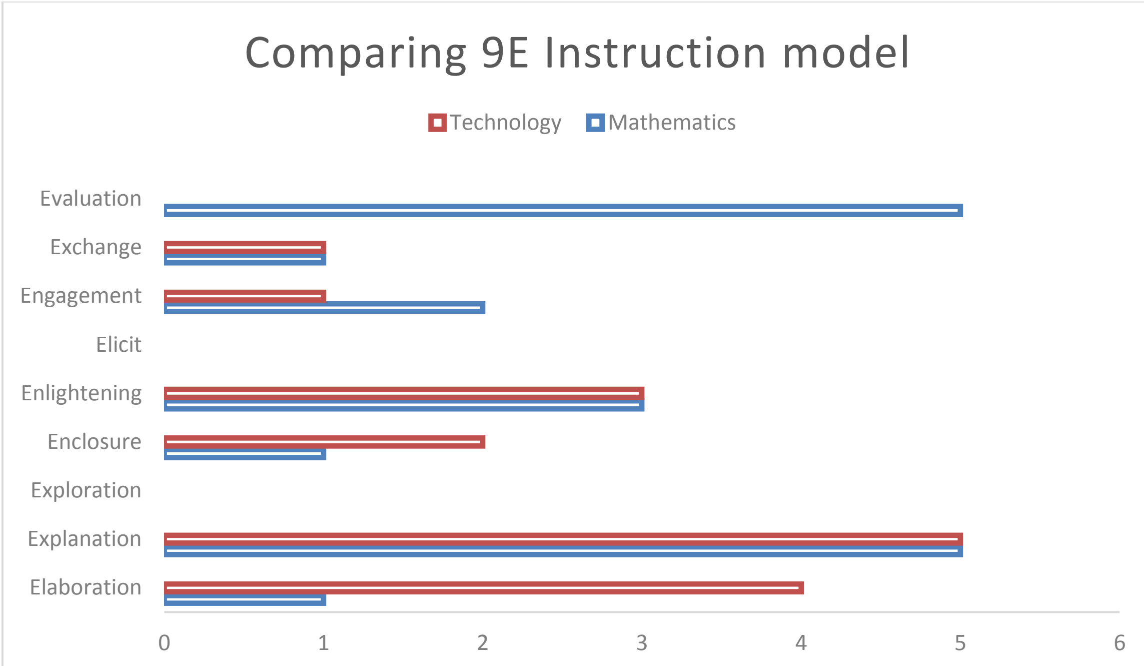

Figure 1. Comparing 9E instructional model

Data indicates that all ten of the pre-service mathematics and technology teachers were capable of executing the explanation phase. They used the descriptive and interpretive methods while in mathematics they also used argumentative and justification explanations. Even though all teachers in both subjects explained various concepts, they revealed different modes of misconception, such as concept misinterpretation or misrepresentation. Similarly, in both subjects six pre-service teachers were able to execute the enlightening phase. They used the data method, demonstration method, graphic representation, and visual representation method. On the other hand, all ten pre-service teachers in both subjects were incapable of executing the eliciting and exploration phase. The elicit phase encompasses prompting of learners' prior understanding. For example, a pre-service teacher can use classroom-interaction, pre-assessment, and multi-media strategies to assess learners' prior knowledge. The exploration phase involves the introduction of new concepts, processes, or skills. For example, a pre-service teacher should present new concepts accurately and in a coherent manner to eliminate confusion. In lesson preparation, these two phases are most critical because they form the structure of the lesson.

Data also showed that in both subjects less than 50% of the time was used to effect the engagement, exchange and enclosure phases. All these phases stimulate learners' participation which promotes the constructivism approach (Littledylee, 2013). According to Shulman (1987:13), PCK encourages a person to "reorganise and partition it (content knowledge), clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstration, so that it can be grasped by students" which was compromised during the pre-service teachers' lesson presentation. Surprisingly, there were more variations in the evaluation and elaboration phases. However, this might have been affected by the nature of each subject. In mathematics, teachers cannot teach without giving learners focused conceptual tasks, whereas in technology, teachers can dominate the lesson without giving learners a focused conceptual task. However, in technology this practice by pre-service teachers is unacceptable because they are expected to give learners a conceptual task. In terms of the elaboration phase, four technology pre-service teachers were able to execute the elaboration phase while only one mathematics pre-service teacher was able to accomplish it. Mathematics deals more with numbers than with concepts whereas technology deals with concepts rather than with numbers. Yet one cannot compromise the significance of these two phases in either field.

In conclusion, this study found that most pre-service teachers in the subjects of both mathematics and technology possess limited knowledge of PCK. In both subjects, the classroom practice of most pre-service teachers does not illustrate a comprehensive knowledge of subject matter or knowledge of students. However, the difference is that only mathematics pre-service teachers possess knowledge of assessment. The data also indicate that 9E instructional practice can be a valuable tool to enhance Field Specific PCK within the fields of mathematics and technology education subjects. For instance, this study found that there are similarities between the instructional practice of mathematics and technology pre-service teachers. Even though pre-service teachers were incapable of executing a particular phase, it is possible to effect such a phase. For example, teachers in both subjects were unable to execute the exploration phase and elicit phase which could be achieved based on the discussion in the finding stage above. Therefore, this study proposes a further investigation of the 9E instructional model that could be used as field specific (FS) PCK within the fields of mathematics, science and technology.

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