Improving Pedagogical Content Knowledge of Pre-Service Mathematics Teachers through Integrated STEM (iSTEM) Strategy among Students of Sokoto State University, Nigeria

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Abstract

Stakeholders in education believed that the integrated Science, Technology, Engineering, and Mathematics (iSTEM) strategy is an effective pedagogy that provides the learners with innovative and higher-order thinking skills needed in the 21st century. Therefore, the purpose of this study was to explore the understanding of Pre-service Mathematics Teachers (PMTs) in improving their Pedagogical Content Knowledge (PCK) in teaching iSTEM strategy. The study was a qualitative research method that allows the participants to spell out their viewpoints on teaching iSTEM strategy. Six (6) participants were purposively chosen and the focus group data collected were analysed inductively using themes, categories, codes and thematic maps developed in line with the research purpose. Reliability includes an investigation of the stability or consistency of responses by checking the transcription and audio recordings. The two independent raters read the transcriptions and formed their categorisation based on the pre-defined set of themes to corroborate interrater agreement which happened to have the content validity index (CVI) of 0.97. The Cohen's Kappa coefficient between the raters was 0.87 suggesting a satisfaction level of agreement between the raters. The results portrayed that, the PMTs are fully prepared to teach the iSTEM lesson in a more holistic manner rather than in bit and pieces into their classroom instruction. Finally, it is recommended that a similar study should be conducted in all level of education as the importance attached towards the iSTEM education globally.

Keywords: Integrated STEM Strategy, PCK, Pre-service Mathematics Teachers

Introduction

The integrated Science, Technology, Engineering, and Technology (iSTEM) strategy is receiving an escalating global attention in tackling the 21st-century challenges on national growth and development. The iSTEM strategy improves the Pedagogical Content Knowledge (PCK) of Pre-service Mathematics Teachers (PMTs) practice to explicitly address teaching pedagogy necessary to have the skills necessary to incorporate the levels of integration, and also have the ability to teach iSTEM course. Specifically, it can be said that the PMTs with a sound knowledge of pedagogy and content can play an important role in teaching iSTEM strategy (Lauermann & König, 2016; Martins & Baptista, 2024). In contrast, the PMTs with limited STEM pedagogy and content knowledge would encounter serious problems in teaching iSTEM strategy (Yıldırım & Sidekli, 2018).

Theoretical Foundations

The theoretical foundations that guided this study includes PCK and Adult learning theory (ALT). These theories hold a central position in providing a lens in which PCK and ALT are blended in preparing the PMTs to teach the iSTEM in their classroom instruction. The theory of PCK is originated from Bruner's social constructivist theory. The constructivist theory is important to this study as the PMTs was trained based on their prior knowledge and experience (Bruner, 1966). The theory of PCK linked to iSTEM in engaging students in hands-on and collaborative learning; students construct actively their own knowledge; teacher act as a facilitator; and engineering design challenges. Additionally, ALT is related to this study because of its principles aims at a learning environment where adults are the learners (Knowles *et al.*, 2014). Virtually, with regards to this study, the iSTEM course is a learning environment in which the PMTs in their 300 level 2023/2024 academic year at Sokoto State University, who are adults generally in the age range of the mid-20s to late 30s were the learners. Supporting the assertion, Mccall *et al.* (2018) mentioned that the students of such age range are increasingly in high enrollments percentage in the high institution of education. Moreover, PMTs have unique learning features that includes: they are rich in experience to draw from what they have already learned in the past; they have the strong knowledge base to decide on their learning styles, and they usually focus on the issues related to their work or personal life.

Literature

The Pedagogical Content Knowledge (PCK) of teaching iSTEM is a paramount strategy used to produce more PMTs' pedagogy and content knowledge that will support the PMTs abilities to teach iSTEM lessons. As such, Pre-service Mathematics Teachers (PMTs) are students at the colleges of education and university levels who are being trained to become certified teachers for schools within a formal teacher education program (National Research Council, 2010). Accordingly, Koirala and Bowman (2003), indicated that PMTs are much more likely to address integrated teaching strategies within and during their teaching method, particularly within their university methods courses understand and teach STEM as an interconnected entity (Corlu *et al.*, 2015). Literature includes many outsets of how to expand PCK into the context of STEM integration in teaching (Kramarski & Michalsky, 2010; Sarkim, 2020). The literature review explicitly elucidates and elaborated in subsequent sub-headings:

2.1 Pedagogical Content Knowledge (PCK)

Pedagogical Content Knowledge (PCK) is defined as a type of teacher knowledge that contributed and developed by a teacher (Halim *et al.*, 2014). The idea of PCK is reliable with or similar to the idea of Shulman's knowledge of pedagogy that is related to the teaching a particular content. According to Shulman (1987); Umameh (2011), PCK is the knowledge of how to teach within a particular subject area. It signifies the blending of pedagogy and content into the understanding of a particular topic, issues or problem is prepared, adapted and represented to the diverse interests of the learners and abilities for presented and instruction. Considering what teachers need to know, Shulman (1987) determine the concept of PCK being consisting of pedagogical knowledge and content knowledge of effective instructional approaches. Also, the PCK is a type of knowledge that comprises an understanding of making the learning of specific content easy or difficult to learning and strategies to reorganise the understanding of learners. So, it is the blending or integration of teachers' pedagogical knowledge and content knowledge that originated from the PCK.

Furthermore, pedagogical content knowledge is a form of knowledge that is unique to teachers, and in fact, it is what the teaching is all about. It is concerning how the teacher relates to what they understand about teaching what they know about what they teach. However, researchers building on the Shulman's framework insights (Ball *et al.*, 2005; Grossman, 1990; Loewenberg Ball *et al.*, 2008) believe that many-dimensional acts of teaching are more than knowing the information; it is more than just an engaging delivery. PCK captures the teachers' understanding of knowledge of content within the dynamics of transforming that knowledge for students. These also consist of specific knowledge of content for teaching subject matter to indicate the complex nature of knowledge used during teaching (Vierra, 2011). Likewise, Shulman (1986) describe that the teacher need not only understand the meaning of something but the teacher needs to understand more about why it is so, on what ground it can be asserted and to be able to communicate it to the students.

2.2 Integrated Science, Technology, Engineering and Mathematics (iSTEM) Approach

Many studies have been conducted within the last decades investigating and examining pre-service teachers with regards to integrated STEM content into their instruction (Berlin & White, 2012; Burrows & Slater, 2015; Frykholm & Glasson, 2005; Furner & Kumar, 2007; Koirala & Bowman, 2003; Niess, 2005; Stohlmann *et al.*, 2012). These studies all focus on providing meaningful learning requirements for PMTs to encourage integration and collaboration within the classrooms. This is in conformity with Stohlmann *et al.* (2012) statement on consideration for teaching iSTEM education that the teaching of integrated science and mathematics provide a good basis for teaching iSTEM education. Although iSTEM is considered to be very important in resolving from teaching single or separate STEM disciplines to teach in a more connected manner. There is a lack of preparing students in Nigeria to teach iSTEM lesson. Even in the situation where teachers attempt to teach all STEM subjects, the uncertainty regarding how well teachers truly understand each of the four STEM subject areas outside a specific area is of great concern (Ugo, 2016).

2.3 Pedagogical Knowledge (PK) for Teaching the iSTEM Course

The knowledge of pedagogy is necessary for improving the activities of STEM stakeholders in managing their classroom efficiently (Eckman *et al.*, 2016; Ejiwale, 2012). In relation to this, the pedagogical knowledge (PK) of the teachers and the content of the iSTEM needs attention. In view to this, Lauermann and König (2016) indicated that the teachers deep understanding of PK might play an important role in employing various instructions for improving a deep knowledge of the content and skills. This study used PK to highlight on the need to understand how best pedagogy employed in preparing the PMTs in teaching the iSTEM lessons.

2.4 Content Knowledge (CK) for Teaching the iSTEM Course

On the other hand, Knowledge of content for teaching iSTEM refers to the development of a deep understanding of content that the PMTs need to have for teaching iSTEM. Thus, Moore *et al.* (2014) identified the development of a deep understanding of content as one among the six characteristics of STEM integration. As such, Content knowledge (CK) includes the actual knowledge of the subject matter that is to be learnt or taught, that has the potential to strongly influence how PMTs represent the content and design a learning experience and strategies to support the learners about the content to be taught. In this regard, Kaya (2009) revealed that the CK level of the pre-service teachers plays an essential role in the improvement of their PCK. The researcher further explained that the pre-service teachers with weak knowledge of CK had superficial knowledge (Kaya, 2009). It was further explained that the pre-service teachers with strong CK increase students understanding (Kaya, 2009; Van Driel *et al.*, 2002). In supporting this, the literature indicated that successful integrated STEM can effectively achieve with the development of CK (Eckman *et al.*, 2016; Halim *et al.*, 2014; Stohlmann *et al.*, 2012). In this study, the PMTs need to have a deep understanding of content knowledge in their ability to teach iSTEM in their future classroom instruction.

Although, due to the scarcity of empirical research on the iSTEM in Sokoto State Nigeria, these studies serve as an excellent starting point for researchers who wish to drive the future of pre-service teachers for iSTEM education. Numerous research studies conducted have promotes integration through effective means for not only teaching iSTEM education but also in raising the perceived value of iSTEM education among pre-service mathematics teachers (Furner & Kumar, 2007; Koirala & Bowman, 2003).

Research questions

This study explored the understanding of the PMTs in improving their PCK in teaching iSTEM strategy and the following research questions (RQ) guided the study.

1. How would iSTEM training improve the Pedagogical Knowledge (PK) of PMTs in teaching iSTEM course?
2. How would iSTEM training improve the Content Knowledge (CK) of PMTs in teaching the iSTEM course?

Methodology

This study adopted qualitative research method using case study design. A qualitative case study intensively allows the researcher to holistically analyse and interpret a phenomenon within its reality

(Creswell & Poth, 2017; Merriam, 2009). In this research, each participant was regarded as a case that helped and guided the researcher to obtain detailed information in answering the research questions earlier presented.

The participants in this study were the pre-service mathematics teachers (PMTs) who are in their 300-level teacher training programme in Sokoto State University (SSU) Nigeria. Purposive sampling was used in choosing a set of Six (6) participants that formed the focus group interview.

To assess the degree to which the interview was delivered as intended, the researcher focussed on training the students for better understanding of the five levels of STEM integration that included single, combine, multiple, engineering design and fully integrated STEM. To ensure the fidelity of the training, the researcher organised the participants to work in a small group of four to six in a group. During the intervention, the researcher acted as a facilitator that guided, assisted and emphasized on active participation and engagement of the participants. These features helped in developing learner's creativity, collaboration, brainstorming of ideas, team-work and logical thinking. The PMTs construct their learning environment and organised their learning which made them to improve in the teaching of iSTEM course under the guidance of the researcher.

In spite the fact that, the researcher is a member of the department of science education in the university where this study was conducted, "an introductory letter" seeking permission to conduct the research was presented to the university through the Head of the department. Permission was granted for the conduct of the research. To protect the right of the research participants as literature suggests (Kumar, 2018), the researcher presented a consent form to all the participants. Participants were also advised that they had the right at any point to withdraw from the study. The participants were also told that their participation would also be kept confidential and anonymous to protect them from a negative consequence or any harm. As such, the researcher used pseudo names to protect their identities. Also, to reduce the biasness, independent validators outside the university domain and experts were used for reviewing the research instruments.

Assessing iSTEM-SIQ Instruments

The integrated STEM semi-structured interview questionnaire (iSTEM-SIQ) was the instrument used in this study. The semi-structured interview was used across disciplines because it gives the participants the opportunities to spell out their viewpoints on the phenomenon under study (Creswell, 2013). The interview was recorded with an audiotape via a smart-phone application named voice recorder and saved as audio files on an external storage unit and then transcribed the audio and manually analysed (Braun & Clarke, 2006). The focus group interview protocols were developed based on the literature; every interview question outlined to answer one category of the research questions. The focus group interview was lasted approximately 120 minutes duration and conducted at the mathematics laboratory. The focus group interview depends on the number of questions and the complexity of the issues but within one to two hours are sufficient for most discussions (Dilshad & Latif, 2013). During the interview, each participant in the group was asked to describe how the iSTEM training built their interest to teach the iSTEM lesson. Also, they were asked to describe how their overall participation helped them to grow and prepare to enter into the teaching of iSTEM content. The participants were also asked to identify their interest in pedagogical knowledge and content knowledge for teaching iSTEM lessons.

The reason for forming this set of the focus group interview is in line with the literature that, a focus group interview works well with around six to eight interviewees in each group (Creswell, 2013). Moreover, Dilshad and Latif (2013) suggested that the size of the focus group should range from six to eight participants preferably and it seem to be suitable for the number of the qualitative interview to reach saturation level (Guest *et al.*, 2006). It is argued that if the number is less than six, it is difficult to provide the synergy required. While a group with more than eight participants can be difficult to control (Krueger & Casey, 2002, 2014). However, interviews with the focus groups have their limitations, as some participants are reluctant to contribute to the discussions. Thus, in this study, the participants willingly said their mind and voluntarily participated.

Validity of the Instruments

In this study, the validity of the instruments was accomplished with the content validity index (CVI) of 0.97 obtained while distributed the instrument for validation to experts for content and construct validation. As a result of their input, all the items found to had substantial validity that deals with the checking of the accuracy of the results by employing certain strategies (Creswell, 2013). Some of the strategies used to address the trustworthiness of the data are confirmability, credibility, dependability and transferability. These qualitative strategies mentioned in turn uses criteria like reflexivity, thick description and triangulation (Golafshani, 2003).

Reliability of the Instrument

The reliability of the instrument includes an investigation of the stability or consistency of responses. The two independent raters read the transcriptions and formed their categorisation based on the pre-defined set of themes to corroborate interrater' reliability. The Cohen's Kappa coefficient between the raters was 0.87 suggesting a satisfaction level of agreement between the raters. The researcher took the following approaches to check the qualitative interview reliability in this study: checking the transcripts and audio recordings to make sure that, they did not contain any unclear terms during transcription; authentication of the codes and their definitions.

The qualitative information or data was analysed inductively using thematic analysis as proposed by Braun and Clarke (2006) in answering the research questions. The thematic analysis employed was through the following six phases: Familiarising oneself with one's data; Generating initial codes; Searching for themes; Reviewing themes; Defining and naming themes; and Reporting. In this study, the researcher followed the above phases in analysing the data based on the individual responses, making codes, compared and categorised the themes with the findings of transcription of the focus group interview obtained and subsequently interpreted the findings. In this study, the interviewees that formed the focus group are coded as: PMT1, PMT2, PMT3, PMT4, PMT5 and PMT6 participants. The overall findings are presented in the subsequent subheadings.

Results

This part presented the overall findings of the study. The findings have been categorised into two subsections: interview analysis on PK for teaching the iSTEM course and interview analysis on CK for teaching the iSTEM course. The information was analysed using thematic analysis in answering the research questions.

Interview Analysis on PK for teaching the iSTEM Course

This section was designed to answer the qualitative research question in exploring how the iSTEM course training improves the PCK of PMTs in teaching iSTEM using thematic analysis. This section gives the 6 participants (PMT1, PMT2, PMT3, PMT4, PMT5 and PMT6) that formed the focus group interview the opportunity to spell out their viewpoints about how the iSTEM course training improved their PCK towards the teaching of iSTEM course.

From the interview results, all the participants agreed that the iSTEM course training conducted helped them to improve on how they might use integrated STEM disciplines in their instructions. Two participants (PMT3 and PMT6) mentioned engaging the learners in learning engineering content by bridging mathematics and science disciplines as the way in which they would use iSTEM in their teaching instruction. Also, PMT1 and PMT4 said, "……connecting all the four STEM disciplines in one lesson to solve real-life problems". Whereas PMT1 and PMT2 said "…… can be through team-work, collaborative learning and student-centred approach to teach the iSTEM lesson. The participants were further interviewed about their preparedness to teach integrated STEM lesson.

All the six respondents had agreed that they are fully prepared to apply and teach the iSTEM lesson in their classroom instruction. However, before the iSTEM training, the participants had difficulties and did not have any orientation on how to teach iSTEM lesson, but now they had an improvement and feel relaxed and prepared to teach the iSTEM lesson and feel confident in applying integrated STEM strategies in the teaching instruction. Similarly, the participant PMT2 mentioned categorically that the iSTEM training gave them the opportunities to teach iSTEM lesson in a more holistic manner rather than in bit and pieces. Relatedly, PMT3 and PMT6 all mentioned application about the integration of STEM contents. Conclusively, the iSTEM training was found to have a positive impact on the PMTs in teaching the iSTEM course. This led to two categories that supported the PK, which included: using the iSTEM in teaching instruction and preparations for teaching the iSTEM lesson. Thematic Map for PK is illustrated in Figure 1 below.

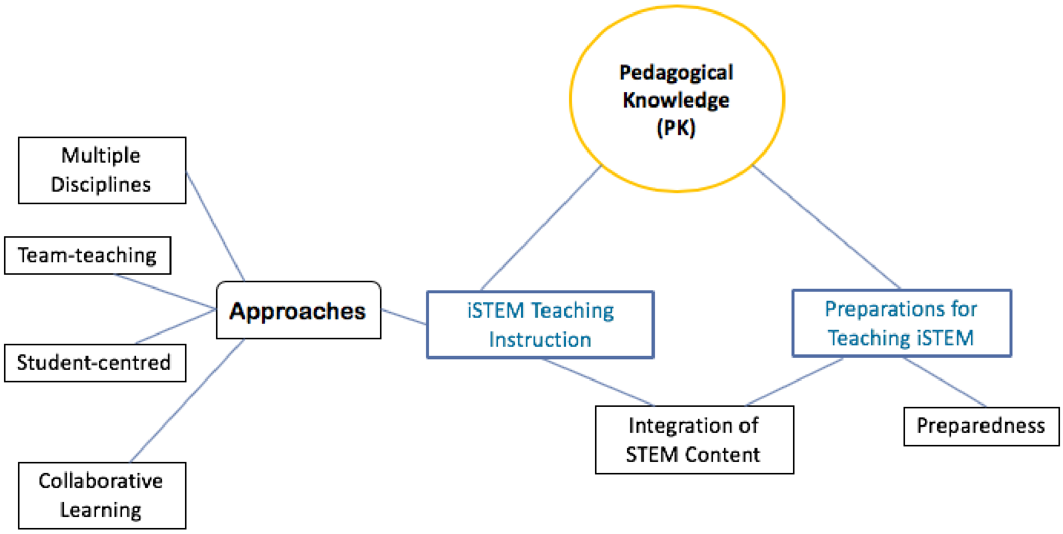

Figure 1: Thematic Map for PK

Figure 1 shows the thematic map for PK resulted from two different categories which comprised preparations for teaching iSTEM and iSTEM teaching instruction which were further collated from the identified codes. The different categories of PK were discussed more in details as:

Theme 1, Category 1: Using the iSTEM in Teaching Instruction

This category contains pedagogical knowledge practices that advocated into five approaches with different codes which includes integration of STEM content, connection of multiple STEM disciplines, team teaching, student-centred approach, and collaborative learning. Among these codes, integration of STEM content focuses on the connection of all the four STEM disciplines as mentioned by PMT4. Whereas, supporting the practice with implicit connections of the teaching instruction to the other disciplines. The participants, PMT3 and PMT6, mentioned Multiple disciplines as the teaching instruction that focus on the connection of mathematics, science and technology or engineering.

Theme 1, Category 2: Preparations for Teaching the iSTEM Lesson

This category contains two different codes which supported the participant's preparations for teaching the iSTEM lesson, which included preparedness and integration of STEM content for teaching the iSTEM lesson in their future classroom instruction. For the preparedness, all the participants indicated that they feel relaxed, satisfied and prepared to teach the iSTEM lesson. However, advocating the practice with the connection of teaching the iSTEM lesson, participant PMT2 equally mentioned the integration of STEM content approach as the teaching of the iSTEM in a holistic manner rather than bit and pieces.

Interview Analysis on the CK for teaching the iSTEM Course

This interview session about the content knowledge for teaching the iSTEM course was conducted with the same focus group interviewees. In this regard, each of the member of the focus group was asked about his CK for teaching iSTEM, and they responded about their knowledge of science in which they stated that they had a good knowledge of science. They also, went ahead to explain science as the knowledge that usually concerned with the study of nature and the behaviour of natural things (PMT6). Mathematics as a tool for the understanding of science (PMT1; PMT3). Participants had explained that before receiving the training, they had difficulties in putting into action or in explaining more about their knowledge of science. Also, they mentioned their difficulties to integrate mathematics with engineering and or technology in teaching mathematics. But, now they had a positive view of knowing the relevance of science. Thus, the participants were further expressed their views regarding the field of science in which they were good at and they mentioned few subjects such as chemistry, physics and biology. For instance, PMT4 and PMT5 mentioned agricultural science and equally PMT5 include computer science as part of the science field. The researcher further moved to the next question whereby the participants were asked to give their contribution regarding integrating the knowledge mentioned in which they are good at in connection with mathematics. Hence, all the participants agreed that they could integrate their knowledge of science with mathematics. They all answered “yes”, and when they were asked to explain further, PMT4 specifically mentioned that both science and mathematics could be used in collecting, recording, organising data and communicating the results. Also, the participant PMT6 mentioned that both science and mathematics are closely related and the disciplines use time relationship, and they are both concerned with collecting and interpreting the data whereas PMT3 shows that both disciplines enhance learners’ motivation and their reasoning ability through the use of technology and hands-on activities in solving real-life problems. The participants were further interviewed about using technology in teaching will enhance the knowledge of mathematics.

Based on the interview results, the participants gave their views on using technology in teaching mathematics lessons in which PMT6 indicated the use of projector, computers and making PowerPoint presentation in teaching iSTEM course. Also, PMT3 mentioned the incorporation of multimedia, scientific and or graphing calculator in teaching iSTEM lessons. More so, most participants mentioned that the use of technology in teaching mathematics increases the learners' excitement and make the lesson interesting and fun. It is viewed that it makes the learning to be easy as mentioned by PMT5 in his response. Also, PMT2 added that it builds skills and engages the learners to work in a team. The participants were further interviewed to explain from their viewpoint the word "engineering" and also explained how they would integrate engineering in mathematics. Likewise, the participants were asked about the concept of "Engineering". They mentioned that it is a branch of science and technology that is concerned about the design, invention and building of materials needed to make human life easier. Consequently, when the participants were asked on how they would integrate engineering into mathematics, PMT4 mentioned that engineering could be incorporated through digital design that can be developed on a computer into a physical object to aid the teaching of mathematics. Likewise, PMT3 added that it could be through incorporating images in the teaching of vectors, basic statistics and matrices and matrix transformation and representation in the teaching of mathematics. Based on the responses obtained the participants after receiving the iSTEM training, it is indicated that their understanding about incorporating science, technology, and engineering in the teaching of iSTEM has been elicited.

The overview of the theme, category, sub-category and codes showing exploration of CK for teaching the iSTEM course were extracted, and similar codes mentioned by the participants were grouped. The theme indicated participants content knowledge to the actual knowledge of integrating mathematics content that the participants need to have for the teaching of the iSTEM course. This led to six categories that supported the CK as illustrated in the thematic map in Figure 2 below.

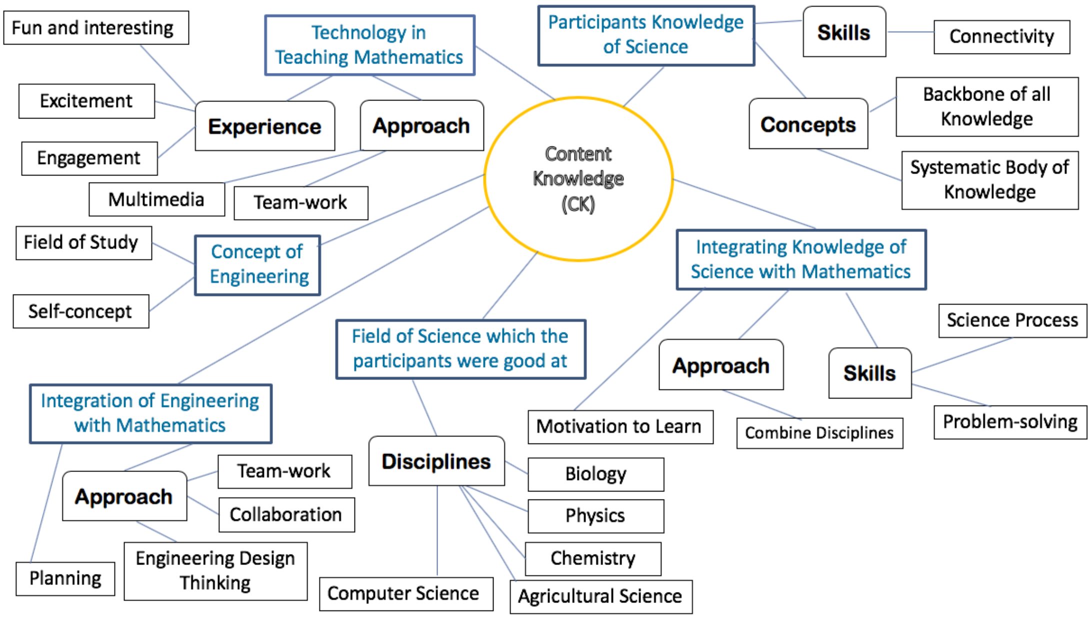

Figure 2: Thematic Map for CK

Figure 2 shows the thematic map for CK which resulted from six different categories which comprised participants knowledge of science, field of science which the participants were good at, integrating knowledge of science with mathematics, technology in teaching mathematics, concept of engineering and integration of engineering with mathematics which was further collated from the participants identified codes. The different categories of CK were discussed more in details as:

Theme 2, Category 1: Participants knowledge of Science

This category encompasses content knowledge practices that advocated into different codes which include conceptions of science as the backbone of all knowledge, systematic body of knowledge and connectivity. Among these codes, a systematic body of knowledge focus on the systematic way of modifying the natural world and also an organised body of knowledge as rightly mentioned by PMT1 and PMT4 relatedly. Also, advocating science as the backbone of all knowledge, PMT2 stated her understanding of science as is mostly concerned with the collection of facts to understand how the natural world works.

Theme 2, Category 2: Field of Science which the participants were good

This category contains five different science disciplines with codes supporting the participants' field of science which they were performing better. The five science disciplines mentioned includes

Biology; Chemistry; Physics; Computer Science; and Agricultural Science. Theme 2, category 3 is about integrating the knowledge of science with mathematics.

Theme 2, Category 3: Integrating Knowledge of Science with Mathematics

This category supported the content knowledge skills, and approaches that advocated into different codes which include science improves motivation to learning and reasoning ability, science improves problem-solving skills and science process using collection of data, recording, organising the data and communicating the results. Particular among these codes, motivation to learn enhances through the use of technology and hands-on activities as precisely mentioned by PMT1.

Theme 2, Category 4: Technology in Teaching Mathematics

This category (technology in teaching mathematics) incorporates content knowledge practices that advocated into five different codes for using technology in teaching mathematics comprised excitement, make teaching fun and interesting, engaging, team-work and use of multimedia. Among these codes, fun and interesting make the lesson more excited and enjoyable to the learners as exactly mentioned by most of the participants. Additionally, advocating on the code excitement, PMT1 and PMT4 mentioned that using technology in teaching makes learning easier and increase interest in the lesson. Moreover, PMT3 and PMT6 mentioned that using multimedia in teaching incorporated projector, scientific calculator and computers in making PowerPoint presentation.

Theme 2, Category 5: Concept of Engineering

This category expressed the view of the participants about their knowledge of engineering. These advocated into two different codes which included: Engineering is a field of study and a self-concept. Among these codes, the field of the study indicated that it is a branch of science and technology focused on the design, building and structures as rightly mentioned by PMT1; PMT5 and PMT6. Also, advocating on the code self-concept, most of the participants indicated their understanding of engineering as it is deeply rooted with the principles and rules of mathematics. Theme 2, category 6 below is about the integration of engineering with mathematics.

Theme 2, Category 6: Integration of Engineering with Mathematics

This category contains four different codes supported the participants' approach and the ability for team-work, engineering design thinking, planning and collaboration. For the team-work, most of the participants indicated that team-work enables the learners to participate as a contributing member of the group (PMT1; PMT3; PMT5). However, advocating the practice with the connection of teaching the iSTEM lesson, participant equally mentioned engineering design thinking as a knowledge designed through construction and dynamics using principles of mathematics. Nonetheless, planning through brainstorming and development of multiple solutions was indicated by PMT2. Whereas, collaboration signifies the ability to make effective communication of ideas among the peers as rightly mentioned by the participants (PMT2; PMT4; PMT6). In a nutshell, the foregoing has explained the overall findings of the study.

Discussions

The prime objective of this study was to investigate how the iSTEM training can improve the PK and CK of PMTs in the teaching of iSTEM course. The PMTs PCK in teaching iSTEM was described based on the area of pedagogical knowledge and content knowledge for teaching the iSTEM course. The sub-section below discusses of the overall findings relating to pedagogical knowledge of the PMTs for teaching the iSTEM course after the iSTEM course training.

Pedagogical Knowledge of PMTs for Teaching iSTEM Course

Pedagogical knowledge is the act of teaching, training and instruction (Hartati *et al.*, 2019) it also includes educational objectives, teaching and learning processes, knowledge of the approaches or procedures used in the classroom, the essence of the target audience and the awareness evaluation strategies (Norton, 2019). The findings of this study indicated that participants agreed that the iSTEM course training helped them improved positively on how they might use their knowledge of pedagogy in teaching iSTEM in their future classroom instruction. This idea of pedagogy in teaching the iSTEM course is fundamental for an effective retrospective teaching. This idea concurred with the Shulman (1986) explanations which gave the impression that an acceptable description of the forms of knowledge the teachers possessed must accomplish to carry out the teaching job over the iSTEM education. In as far as the iSTEM teaching is concerned, O'neill *et al.* (2012) outline three components that support STEM pedagogical development practices in their classroom: First of all, teachers must be willing to leave their comfort zone in their current teaching methodologies. Secondly, teachers can not completely change their practices without guidance. Thirdly, students are already trained to learn in a certain way; therefore, STEM teachers must promote new ways of learning and think through real-world problems that create meaningful connections.

The findings also revealed that engaging the pedagogy of learners in engineering content by bridging mathematics and science disciplines as to how they would use integrated STEM in their teaching instruction (Frykholm & Glasson, 2005; Furner & Kumar, 2007). Moreover, the study of Stohlmann *et al.* (2012) and Breiner *et al.* (2012) found that connecting all the four STEM disciplines in one lesson to solve a real-life problem is paramount. Consequently, Okpala (2012) pointed out that, STEM instruction is a meta-discipline which indicated the formation of a discipline that placed the integration of other STEM fields of knowledge into a recent whole rather than in pieces and bits. Likewise, STEM Education is defined as an interdisciplinary strategy to curriculum and instruction by integrating the four fields of study into one cohesive teaching strategies design for the removal of common boundaries and roadblock that stands between the STEM disciplines as literature contends (Friedow *et al.*, 2012; Morrison, 2006; Morrison & Bartlett, 2009; Tsupros *et al.*, 2009). STEM education is a strategy to education which integrates the four disciplines cohesively through an instructional method which utilizes strategies that investigated and explain the teaching and learning between or among more than two of the STEM disciplines, and between STEM disciplines and one or more additional school subjects (Sanders, 2009).

It is also evident from this study that the participants had agreed that they are prepared to apply and teach the iSTEM lesson into their future classroom instruction. The participants further explained that before the iSTEM course training they did not have any orientation on how to teach iSTEM course but after the training, they had a positive improvement and feel relaxed and prepared to teach iSTEM course. This finding concurred with the study of Magnusson *et al.* (1999) that orientation is a general way of seeing or conceptualising the teaching of science and mathematics. The finding added that the participants are ready in applying the iSTEM pedagogy in their future classroom instruction. The participants mentioned categorically that the iSTEM course training gave them the opportunities to teach the iSTEM in a holistic manner rather than in bit and pieces. In the same vein, Okpala (2012) remarked that integration of STEM is an interdisciplinary approach for learning by combining the four disciplines together into one interrelated teaching and learning paradigm, the creation of a discipline placed on the integration of other discipline knowledge into a new indivisible ' whole' rather than in pieces and bits.

The present study also found that the iSTEM teaching instruction can be through team-work, collaborative learning and student-centred approach. These findings are in concordance with the recommendation of Nikirk (2012) that the STEM pedagogical strategies that help the iSTEM teachers to teach and facilitate student learning effectively are through displaying the graphs, students react and learn from visual elements (images, graphics and video) more quickly than reading materials in text format. Findings from this study highlighted the iSTEM course training has successfully improved the PK of PMTs in teaching iSTEM.

Content Knowledge for teaching iSTEM Course

Content knowledge for teaching iSTEM course refers to the development of a deep understanding of mathematics and science knowledge that the PMTs need to have for teaching iSTEM course. Categorically, most participants mentioned that the use of technology in teaching mathematics increases the learners' excitement and make the lesson interesting and fun and make the learning to be easy. To ensure that teachers are successful, they must receive support for developing their content knowledge to be able to effectively teach integrated STEM (Stohlmann *et al.*, 2012; Yıldırım & Sidekli, 2018).

The findings revealed that both the science and mathematics are closely related and the disciplines improve learners' motivation and their reasoning ability through the use of technology and hands-on activities in solving real-life problems. With regard to knowledge of content, pre-service STEM education teachers are considered to be effective in the classroom if they understand their content knowledge deeply and grasp procedures and concepts from different perspectives (Ejiwale, 2012; Halim *et al.*, 2014). Thus, this has been justified by the teachers level of knowledge and understanding of content limited to their capability to teach the content effectively as literature posits (Nadelson *et al.*, 2012). However, content knowledge alone is not sufficient, but expertise related to it is also important for teaching iSTEM. Conclusively, from the responses obtained from the participants after receiving the iSTEM course training, indicated their understanding about incorporating science, technology, and engineering in the teaching of mathematics content.

Conclusion and Recommendation

The study concluded that the iSTEM helps the PMTs to improved positively on how they would use their PK in teaching iSTEM in more holistic manner rather than in bit and pieces in their future classroom instruction using team-work, collaborative learning and student-centred approach. Also, the study was designed to transformed the current curriculum in Nigeria from receiving teaching of separate STEM disciplines to integrated STEM-based practices. It is recommended that conferences, workshops, and seminars should be organised for the PMTs to update their skill in the application of iSTEM strategy. Also, a similar study should be conducted in all level of education as the importance attached towards the iSTEM education globally.

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