

# An Assessment into the Topic-Specific Pedagogical Content Knowledge of Pre-Service Chemistry Teachers in Mole Concept in Abubakar Tafawa Balewa University Bauchi State: An Overview of the Difficult Content and Use of Representation Components

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**Abstract:-** Topic-specific pedagogical content knowledge (TSPCK) is the bedrock in which the subject matter knowledge of a particular topic or content is delivered to students. This study assessed the TSPCK of the pre-service chemistry teachers in Abubakar Tafawa Balewa University with an in depth study of two major components of TSPCK. The two major components of TSPCK which are; The difficult content component and the use of Representation component were considered and this served as the basis for the research questions and the purpose of the study. The Mole concept has been viewed to be a very difficult topic for students to learn over the years. The two research questions sought to determine the extent to which the two components of TSPCK mentioned above were effectively transformed by the pre-service teachers. To answer the research questions, three (3) instruments were used for data collection which are: The TSPCK mole concept questionnaire which was given to the fifty-two (52) final year chemistry education student of the University in order to determine the extent of transformation of the TSPCK components, A TSPCK conceptual understanding test in mole concept which was given to the four selected pre-service teachers who were used as the case study and interview sections was to elicit or see the extent to which they can transform the component of TSPCK in teaching the concept well. The TSPCK conceptual understanding test was analyzed both quantitatively using the scoring rubric and qualitatively by explaining the content of the test written by each pre-service teachers and capturing their responses. Interview responses were coded to align with the TSPCK coding pattern adapted by Mavhunga (2012) and it was analyzed using the content analysis technique. The likert survey questionnaire was analyzed quantitatively using the mean and standard deviation. The pre-service chemistry teachers exhibited different levels of TSPCK in mole concept ranging from developing to

exemplary TSPCK as evidenced by their knowledge of difficult content and the use of representations. Two of the pre-service teachers were able to transform these two components to a large extent while the other two pre-service teachers were to a moderate extent. There was proof of pre-service teachers lacking in certain areas of TSPCK such as the ability to identify some difficult contents and the inappropriate use of representations and analogies. This suggests that there is the need for improvements in pre-service teachers training which would help address the needs of current and future chemistry teacher. To facilitate TSPCK development, new methods need to be explored to connect chemistry education research to practice.

**Keywords:-** Knowledge of Difficult Content, Components, Mole Concept, Representation, Analogies, TSPCK, Pre-Service Teachers.

## I. INTRODUCTION

According to Shulman (1986), Pedagogical Content Knowledge (PCK) includes "the most useful forms of representation of [topics], the most powerful analogies, illustrations, examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that makes it comprehensible to others. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult (that is the misconceptions or wrong ideas that the students of varying grades bring with them to the learning of some topics that are being taught frequently.)"

Pedagogical content knowledge is the combination of different elements which are: Knowledge of subject matter (knowledge of the content/ subject matter possessed by the teacher), Knowledge of students and some likely misconceptions they may have about the subject, Knowledge of curricula as well as a balanced knowledge of curricular saliency, Knowledge of general pedagogy (ie the different methods of teaching the subject)

Pedagogical content knowledge (PCK) is simply knowing what, when, why, and how to teach using a reservoir of knowledge of good teaching practice and experience and the emphasis is being placed on the quality of teaching a specific topic. Pedagogical Content Knowledge (PCK) as a theoretical construct has become a popular hallmark for the teaching profession in many teaching disciplines including science (e.g. Juttner & Neuhaus, 2012). The knowledge that teachers develop with experience is personal and therefore difficult to measure. However, there is some commonality in the way the expert teachers transform content knowledge for teaching, known as pedagogical content knowledge (PCK). For an expert teacher, many of the Pedagogical Knowledge strategies are topic-specific. The quality of PCK within a topic refers to both the conceptual understanding of the different content specific components as well as their interaction and this kind of knowledge is unique from others (Shulman, 1986). When applied to a particular topic, e.g mole concept, it assumes the specificity of the topic and thus differs from the general application within the discipline. Emphasis is placed on the quality of teaching a specific topic, it is called Topic-Specific PCK, (Mavhunga and Rollnick, 2013). Topic-Specific PCK (TSPCK) assists pre-service teachers to consider the specific information about the content knowledge of the topic in relation to prior learner knowledge, structure of the topic in terms of most important core concepts distinguished from subordinate concepts as well as pre-concepts needed to teach each of the core concepts (Mavhunga and Rollnick, 2013), Topic-specific content knowledge is the ability to reason about teaching the topic through five components regarded as important for the transformation of content knowledge, viz: Learner Prior Knowledge, Curricular Saliency, What is difficult to teach, Representations, and Conceptual Teaching Strategies. This study majors specifically on the two major components which are the knowledge of difficult component and the use of Representation components. The idea of Topic specific PCK, whose nature and novelty lies in the quality of teaching a topic by topic provides hope to the possibility of mastering a few in the short term. The idea also holds potential for achieving policy goals that require a teacher to be: 'a specialist in a particular learning area, subject or phase' (SAIRR, 2011). According to Shulman (1986) what makes a topic understandable for learners is PCK by means of representations, analogies, examples and demonstrations.

#### A. Statement of the Problem

From the introduction of the mole in science and in science education, numerous have been carried out, certain studies were carried out to identify difficulties experienced by students when they solve problems involving the mole concept and it has been discovered that pre-service teachers struggle to teach this concept properly to the students and hence they find it difficult in comprehending the topic. The students tends to just understand the mole as a unit quantity and they tend to solve the simple calculation that follows but the major problem is that they fail to form a strategy in solving other problems that related to the mole concept.

#### B. Aim and objectives of the Study

The aim of this study was to assess the topic specific Pedagogical Content Knowledge (TSPCK) of pre-service chemistry teachers in mole concept.

Specifically, the study sought to achieve the following objectives:

- To determine the extent to which pre-service chemistry teachers transform the difficult content component of TSPCK in mole concept.
- To find out the extent to which pre-service chemistry teachers transform chemical representations component of TSPCK in mole concept.

#### C. Scope of the Study

The scope of the study covered the assessment of the topic-specific pedagogical content knowledge of pre-service chemistry teachers in mole concept (the senior secondary two, SS2 aspect of mole study specifically chemical equilibrium) specifically the final year chemistry education students of Abubakar Tafawa Balewa University Bauchi state, Nigeria. This is because they have been exposed to a period of teaching practice during their training and have acquired a level of knowledge of PCK over time and hence was appropriate for this research.

#### D. Significance of the Study

This study would be beneficial to the following set of people;

The Secondary School students: this study would help them understand better those difficult calculations in mole concept and to erase the misconceptions they already have about mole concept because they would be taught effectively by the pre-service teachers by means of an effective transformation of knowledge by the pre-service teachers to make the topic easier and this would properly guide them in subsequent topics in chemistry.

The pre-service teachers would also benefit from this study because it would enhance their understanding of pedagogical content knowledge and also equip them on the best method to employ in teaching specific content or subject

matter in order to facilitate effective teaching and better comprehension of the students. It would also help them understand better the student's prior knowledge and correct their misconceptions about mole concept.

The school Administrators would also benefit from this study as it would help them plan better on how to create a conducive working environment which would enhance the development of teacher's Pedagogical content knowledge.

#### E. Basic Assumptions

Some basic assumptions that guided the study are stated thus:

- The pre-service chemistry teachers have been given equal exposure of teaching (specific teaching methods or techniques) and content knowledge exposure during their pre-service teachers training before they embarked on their teaching practice exercise.
- They have also been exposed to various methods of teaching chemistry (pedagogy knowledge) in the classroom.
- The training they have both in the chemistry content knowledge and the pedagogical skills they have acquired during their undergraduate training have provided them the ability to transform Topic-Specific Pedagogical content knowledge in mole concept.

## II. LITERATURE REVIEW

Pedagogical content knowledge as a valued construct in Science Education Teaching requires more than just the delivery of subject matter to the learners. In addition to subject matter knowledge, teachers need a special kind of knowledge to make subject matter comprehensible for the learners.

#### ➤ Theoretical Framework

Shulman defined the term pedagogical content knowledge as the knowledge for teaching a topic, meaning the “tools” utilized to teach the topic such as the best representations, explanations, and Shulman (1987) concentrates on the types of knowledge that are required in teacher training and the processes trainees needed to go through to becoming a teacher, which he calls ‘Processes of Pedagogical Reasoning and Action. The theory of transformation propounded by Shulman 1987 form a basis for this research. A model of pedagogical reasoning and action advocated by Shulman (1987) had six stages namely: comprehension, transformation, instruction, evaluation, reflection and new comprehensions. Comprehension stage requires understanding of the subject area like numeracy but also values, characteristics, needs and learning interests of students (trainees and their learners). Shulman suggested that in order for a trainee to teach, he needed to transform his understanding or comprehension of the subject matter. Thus transformation requires some ordering, which includes preparation of subject materials, their understanding and

critical interpretation, representation that requires ways in which ideas and concepts of the subject materials can be conveyed to learners using examples, metaphors, experiments and demonstrations, and instructional selections, where teaching and learning styles like lecture, group learning and project work can be applied in a learning environment. The other two transformation processes are adaptation of the previous three in which the teaching and learning materials are adapted to a teacher's generic cohort, and tailoring the adaptations to a teacher's specific cohort. In terms of pre-service teachers, understanding and critical interpretation of the learner's subject matter are important for a trainee before she can teach the subject. Knowing what teaching and learning styles to apply for a particular chemistry topic is also useful in the pedagogical sense and using ways of conveying it is a must. Adapting to generic and to specific cohorts have their use and especially to specific learner group. The third pedagogical process from Shulman's model is instruction. It requires the most important of teaching acts like organizing and managing the classroom, providing succinct explanations, handing out and assessing work, interacting effectively with learners via questions and answers, praise and criticism. Next comes evaluation where understanding or not by learners is monitored in both formal and informal ways. Reflection is used by a teacher to refer back to his teaching where what has worked and what has not, and to rethink how the lesson has gone in relation to achieving its aims. Finally, new comprehension is achieved after going through the previous five stages where documentation, analysis and discussion have been carried out. Shulman suggested that the five stages need not be linear nor need all five stages be experienced. However, the five stages provide, in secondary school teaching, a comprehensive structure for a trainee teacher to follow.

Lee Shulman's (1986) theoretical framework, of pedagogical content knowledge (PCK) has had a substantial influence on research in pre-service teacher education, and consequently, schools of education. This theory is built upon the work of Gross man (2015) oft-cited case studies that concluded that beginning teachers provided with excellent teacher education developed more substantial PCK than novice teachers without this coursework. Teaching is an integration of the teacher's ability to amalgamate knowledge components to produce a teachable form of particular topics, known as Pedagogical Content Knowledge or PCK. In the case of the mole, this would include an understanding of the nature of the mole, and awareness of research into learners' prior knowledge of the mole and the pre-service teacher's knowledge of the mole concept.

## III. METHODOLOGY

The research design used for this study is the Convergent Parallel Mixed-Methods Design. A convergent design that follows pragmatism as a theoretical assumption, is an efficient and popular approach to mixing-methods research (Creswell

& Plano Clark, 2018). The study employed case study as a research strategy of the mixed method. In this study, the mixed methods all have equal weight as each has captured the same or different aspect of the research question.

#### ➤ *Population of the Study*

The target populations for this study were all the fifty-two (452) pre-service chemistry teachers that is the final year chemistry education students of 2020/2021 Academic Session. However, Four (4) of these pre-service chemistry teachers were selected and participated in the case study, they were selected because they have done their teaching practice during their fourth year of study at Abubakar Tafawa Balewa University, Bauchi. These pre-service teachers have acquired both the subject matter knowledge and pedagogical skills which they have applied during the teaching practice. The sample size for this study was four (4) pre-service chemistry teachers which were selected from the total population for the case study. Purposive sampling technique was used to choose the required number. In this study, the criteria used for selection were; participants must offer chemistry education as a degree course, they must be in their final year, they must have completed their teaching practice and finally the students have acquired chemistry knowledge (as measured by the pre-election test on Mole concept) and pedagogical skills to be able to transform TSPCK in mole concept during their undergraduate teaching training programme in ATBU Bauchi. Two (2) males and two (2) females were selected for the case study from the pre-selection test conducted in order to get a balanced and unbiased result for the study. One of the male pre-service teachers gained admission through direct entry and the other three (3) was through UTME. This will also serve as a base of accessing their pedagogical and content knowledge.

#### ➤ *Instrument for Data Collection*

Three (3) instruments were used for data collection in this study these include, TSPCK in Mole Concept questionnaire, interview schedule, and conceptual understanding test in mole concept (using the scoring rubric for analysis). Each of these instrument played a complementary role in data collection because they were meant to answer all the research questions on the two (2) components of topic-specific Pedagogical Content Knowledge (TSPCK).

Analysis of data was made using the following methods:

The TSPCK in Mole Concept questionnaire was analyzed quantitatively using the mean and standard deviation and thereafter conclusions were drawn using the upper limit of the Likert scale. Here, the two research questions were all analyzed quantitatively.

The conceptual understanding test in mole concept was analyzed quantitatively using the TSPCK in Mole Concept Scoring Rubric and qualitatively by explaining in details the result obtained from the case study for the two research

questions and finally the TSPCK in Mole Concept Scoring Rubric was used to determine the pre-service teachers' extent or level of PCK possessed

The face to face interview responses were recorded and transcribed and was analyzed using content analysis qualitatively.

## IV. RESULTS /DISCUSSION

### A. *Quantitative Data Analysis of Pre-Service Chemistry Teachers' TSPCK in Mole Concept*

#### ➤ *Research Question 1*

To what extent do pre-service chemistry teachers transform the difficult content component of TSPCK in mole concept? From the analysis of Data collected on the above research Question, the following findings were made.

The results showed that items numbered (i-iii) on the TSPCK Mole concept questionnaire have means score of 2.09, 3.29, 2.80 and standard deviation of 1.76, 2.88, and 2.43 respectively. From the first item, the mean score obtained was 2.09 and based on the units of the likert scale, it falls under the category "Small extent". This indicated that the pre-service teachers solved some Mole concept related questions, they discovered that most students found the calculations to be very difficult because the results revealed that the comprehensive ability of the students to the calculations was to a small extent and this indicated that more work needs to be done by the pre-service teachers in order to improve on the ability of the students to comprehend the calculations better.

For the second item, the mean score obtained was 2.88 which indicated "Small Extent" from the units of the likert scale. Based on the statement made, this indicated that the pre-service noticed to a small extent that the students understood or found the theoretical aspect of the Mole concept to be easy compared to the calculation aspect and this showed that the pre-service teachers need to make a balance between the calculation aspect and the theoretical aspect in order to facilitate a balanced understanding of the Mole concept as a whole.

From the third item on the questionnaire, the mean score obtained was 2.08, which indicated "Small extent" from the units of the likert scale. This showed that the extent to which the students remember the formula for the calculation in Mole concept was to a small extent. This indicated that the transformation of the difficult content by the pre-service teachers in this area was not effective hence work needed to be done to ensure better transformation in subsequent time.

Finally, based on the cumulative mean scores obtained which were 2.60, this showed that the pre-service chemistry teachers ability to transform the Difficult Content component

of TSPCK in mole concept was to a Small extent (SE). This Implies that the pre-service chemistry teachers' ability to transform the difficult content component of TSPCK in mole concept is to a small extent (SE) hence the pre-service teachers have to be very familiar with the concept in order to identify the difficult content that lies therein and learn to effectively transform it during the teaching and learning process in the class.

➤ *Research Question 2*

To what extent do pre-service chemistry teachers transform chemical representations component of TSPCK in mole concept?

From the analysis of Data collected on the above research Question, the following findings were made. The results showed that items number (iv-vii) on the TSPCK Mole concept questionnaire showed that items iv-vii have mean scores of 3.39, 3.51, 3.26, 3.17 and Standard deviation of 2.92, 3.02, 2.80, and 2.75 respectively. From the fourth item, the mean score obtained was 3.39 and based on the units of the likert scale, it falls under the category "Moderate extent". This indicated that the extent to which the pre-service teacher was able to use instructional materials to explain the Mole concept better was to a moderate extent and this indicated that the pre-service teachers had good ability of transforming the first item statement under the representation.

From the fifth item, the mean score obtained was 3.51 which indicated "Moderate Extent" from the units of the likert scale. Based on the statement made, this indicated that the extent to which the students showed a level of understanding when the pre-service teachers used illustrations to teach the Mole concept is to a moderate extent and this indicated a good transformation ability by the pre-service teachers and a good usage of representations.

From the sixth item on the questionnaire, the mean score obtained was 3.26, which indicated "Moderate extent" from the units of the likert scale. This showed that the extent to which the students showed a level of participation when examples and illustrations were used to teach the Mole

concept was to a moderate extent and this revealed a good ability of the pre-service teacher to effectively use representations and analogies effectively and to transform this item statement of the representation.

The mean score obtained from the seventh item is 3.17 which falls under the category of the unit of the likert scale "Moderate Extent". This revealed that the pre-service teachers were able to use different equations to explain the mole concept better and this was to a moderate extent. This indicated that the pre-service has a good knowledge of the usage of representations including analogies.

Finally, based on the cumulative mean scores obtained which were 3.20, This showed that the pre-service chemistry teachers ability to transform the Representation component of TSPCK in mole concept was to a Moderate extent (ME). This revealed that the pre-service teachers were able to use appropriate instructional materials, Representations or analogies to teach the concept better.

*B. Qualitative Results /Discussions*

➤ *Pre-service teachers Understanding of difficult content component*

The classroom observation, Likert survey questionnaire and conceptual understanding Test of TSPCK in Mole concept assessed all the aspects of the topic the Pre-service teachers found difficult when teaching the Mole concept, It became very clear that the different aspect of the topic presented different grades or levels of difficulty for each Pre-service teacher. Two of the pre-service teachers by name Salamatu and Tanko explained that their students struggled to understand the number of moles as "The mass of a compound or element divided by the molar mass of the compound or element. while Ajoke and Dauda stated that there was no difficulty for the students in comprehending the topic taught.

The table below captured the areas of difficulty reported by the pre-service teachers in teaching the mole concept specifically Salamatu and Tanko

Table 1 Pre-service teachers Reported Challenges of What Makes Mole concept Difficult to Teach

Some Difficult sub-concepts in Mole concept	Salamatu	Tanko	Ajoke	Dauda
1. Definition and comprehending the meaning of Mole	+	+		
2. Calculating the molar mass of a compound	+	+	+	
3. Getting the atomic mass of an element	+			
4. Calculating the number of Mole of a compound	+	+	+	+
5. Differentiating between the relative atomic mass and relative molecular mass	+	+		
6. Identifying the SI unit for Mole and mass	+	+		

➤ *Pre-service teachers understanding of the use of Analogies/Representations.*

The conceptual understanding Test of TSPCK in Mole concept provided data on pre-service teachers' use of models, analogies and representations in the unit of Mole concept. For the analogy section, Pre-service teachers were asked to state explicitly the analogies they used when teaching the Mole concept. Ajoke wrote about the periodic table, how she used to explain to the students how the atomic number and mass number can be obtained and the position of each element on the periodic table indicating the groups and the periods. Salamatu, Tanko and Dauda all used verbal illustration and written examples on the board to explain the compounds, elements, atoms etc.

Analogies can be useful for making the abstract nature of chemistry to be more comprehensible, interesting and very familiar for the students. Only Ajoke included analogies in her instruction of the Mole concept, which is a strength of her TSPCK. Being able to help her students compare an abstract topic to something familiar in the real world or describe the motivational function is helpful for students. Salamatu, Tanko and Dauda did not incorporate analogies into their instruction of the Mole concept. Following the section on analogies on the Conceptual understanding Test on TSPCK in Mole concept, teachers were asked to list the diagrams, illustrations, examples, and representations they used when teaching the concept. Diagrams and representations may be common tools for the pre-service chemistry teachers, they also need to be aware of why some students may be confused if they are using representation for the very first time and some may not be confused but rather find the teaching very interesting and engaging. Three of the pre-service teachers had no in-depth familiarity with Representation. If teachers had a working knowledge of the diagram or had utilized it in their classrooms, perhaps they would be able to say with greater certainty whether or not it was useful and the potential challenges it might pose for students.

*C. Interview Section*

This section described the interview process for the pre-service teachers that have been completed. The first question asked Pre-service teachers to describe the most difficult concepts to teach the students and how they approached the difficult concepts when teaching. Next, the pre-service teachers were asked if they used any form of representations or analogies and to explain vividly the representations used to teach the mole concept. All the questions asked in the interview were from the two research questions that guided the study.

The interview responses were coded to identify pre-service teachers' knowledge and beliefs about Mole concept. These codes allowed for immediate identification of pre-service chemistry teacher's PCK. The TSPCK obtained were some students' learning difficulties (difficult concept) and

teaching aids. The interview covered the two (2) components of TSPCK which are; difficult content component and the use of representations,

➤ *Interview responses by pre-service teachers about the Difficult Content Component*

During the interview, the pre-service teachers were asked series of questions concerning the difficult aspect of the Mole concept, the aspect they found difficult to teach as pre-service teachers, the aspect the students found very difficult to understand, how they were able to identify this difficult content, how they were able to transform this difficult content in order to make it understandable for the students etc. Some of the responses given by the pre-service teachers to the questions asked included:

What assisted you in identifying the most difficult content to teach"

In response to the above question, Tanko said that "YES! There is a difficulty! And this difficulty is when they are... It's not easy for them to understand the Mole concept without know the molar mass. And for you to know the molar mass, you have to introduce some topics which would also take some time. At least you have to look at the atomic mass and the molecular mass, that is molarity. Sometimes you even have to go for periodic table to know the... to know the molarity very well "

When asked what assisted him in identifying this difficult concept, he said

When I evaluated them at the end of the lesson, I gave them some problems to solve, then from there, I realized that... problem.

According to Ajoke, her response to the question was

"OK, since I found out that the students are having problem in maybe identifying the molar mass and the mass number of a certain element, then I go back, I try to look for something else I can actually do that can make them to like understand this concept very well, so for the mass number, I only tried to differentiate that OK, the numbers above the elements are known as the mass number while the ones below are the atomic number and you can get the atomic number by just counting them the way they goes eh, number the way they are being arranged in the periodic table, OK, Hydrogen is 1, Helium is 2 these are the atomic number but when it comes to the mass number, you just multiple the atomic number by 2, that's all. Like for some, like most of the element works that way, but just few of them doesn't or are not applicable.

She gave a detailed explanation of how the mass number as well as atomic number can be easily identified using the periodic table.

Salamatu went further to say that "some things were difficult especially in differentiating the atomic number and mass number of elements. Also, while asking them questions as regards the concept being taught, they could not answer, so I had to go through it again to explain it better and then I ask them the questions again which they later answered correctly". She went further to explain "... And for the calculation aspect that they found very difficult initially, I had to break it down in bits by bring out all the parameters given in each question before solving and with that, they tend to follow and understood it properly".

➤ *Interview responses by pre-service teachers about the Representations and use of Analogies component*

When the pre-service teachers were asked if they Used any representation or analogies. Three of the pre-service teachers stated that the Used verbal examples and illustrations like using Sodium Chloride (NaCl) and water (H<sub>2</sub>O) as examples of compounds to teach the concept. Only Ajoke stated clearly and presented the representation or analogy Used for the teaching of the Mole concept. When asked how she incorporated these analogies in the teaching process, this was her response

"Yes, I only Used a chart, like the diagram of the periodic table indicating the atomic number of each and every element and the mass number of each and every element and I also try to show them the groups and the period, using that chart or diagram.

## V. IMPLICATIONS

The pre-service chemistry teachers reported that the TSPCK training given to them was not enough and the time frame for the training was too short to help them develop a strong and stable PCK. TSPCK is known to develop over time with constant training, practice and experience, if the foundation is not well established at the pre-service level, there is no strong evidence that it would develop once the pre-service teacher enters the profession. The major aim of the teacher preparation program is to produce teachers who may exhibit strong and sufficient content knowledge (subject matter knowledge) and pedagogical knowledge (method of teaching) at the end of the certification examination. The TSPCK may be deficient and lacking in certain areas if the training is not properly carried out. The content knowledge is very necessary for TSPCK transformation, the results of this study showed that two of the pre-service teachers, did not necessarily have greater TSPCK in the advanced calculation aspect of the mole concept. Tanko and Ajoke took some advanced calculations in mole concept when teaching the students

➤ *Recommendations*

The Chemistry educational system in Nigeria has gradually become void of practical activities and majors on the theoretical aspect where students majorly read and memorize just to pass test and exams without necessarily having a balanced knowledge of what has been taught with some real life applications. The emphasis has gradually become on the performance of the students in external examination which has become a yardstick in measuring the quality of the teachers' PCK rather than the actual knowledge gained by the students. Furthermore, the curriculum needs to be revisited in order to concentrate more on the practical aspect as well as real life application, inquiry and conceptual learning rather than on rote memory

➤ *Suggestions for Further Studies*

Subsequent research should evaluate pre-service teacher preparation training programs that emphasize TSPCK development on a large scale with measured student outcomes over several years. The TSPCK competency of these pre-service teachers should be measured before they enter into the teaching field competency should be measured prior to entering the field as well as through exploration of its effects on pre-service teacher retention and confidence. Similarly, research should explore the TSPCK development of pre-service teachers who stay niched in a professional learning community compared to those who do not, in order to examine how TSPCK changes over time for groups of pre-service teachers.

Also, research should examine how TSPCK develops as a result of development opportunities for pre-service teachers. If pre-service teachers are deficient in their knowledge of Mole concept, they may be deficient in other areas of the curriculum. Further studies should examine the best means of supporting TSPCK development in pre-service teachers via tasks, exams, modules, and workshops to determine which types of strategies show the greatest benefit to the pre-service teachers and their students.

Lastly, future research or study Should be conducted to explore the TSPCK in other Difficult topics in chemistry for instance La charteliat principle Redox Redox reaction, stoichiometry etc.

## VI. CONCLUSION

This study clearly indicated the level of the PCK of the pre-service chemistry teachers as well as their balance understanding of the components of TSPCK and how to transform these components appropriately in the classroom during the teaching and learning process. The result of this research study indicated that the pre-service teachers' knowledge of the subject matter is still developing and hence needs improvement alongside an intensive training. The pre-service teachers ought to have the ability of identifying the

areas that students find very difficult in comprehending and device means of addressing the challenges encountered by the students. They also have to develop their proper use of representation, analogies, demonstration, examples, explanation etc in order to facilitate easy understanding of the subject matter by the students leading to the effective transformation of the components of TSPCK.

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