Teachers' Perceptions of Essential Mathematics Concepts in Teacher Education Mathematics Courses:

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Abstract

This study investigates pre-service teachers' perceptions of essential components of mathematics education courses offered in primary colleges of education in Botswana. Data for this study were obtained from 11 3rd year student teachers who enrolled in mathematics education courses. The student teachers responded to structured interview protocol questions designed for the study. The analysis of data was framed in qualitative tradition using excerpts taken from student teachers' responses .The results of the study suggest that student teachers perceived 'history of mathematics, modelling, contemporary issues in mathematics education, beliefs and attitudes, mathematics and culture as non-essential parts of mathematics education. The results of the study also suggest that mathematics education courses offered by primary colleges of education do not prepare pre-service teachers for degree courses that would be taken at the university level. Implications for teacher education program are discussed in the light of the findings.

Key Words

Essential Components, Pre-service Teachers, Mathematics Education, Diploma, Perceptions

Introduction

Over the past two decades, reforms occurred in teacher education mathematics courses in Botswana primary colleges of education. The reforms were introduced to meet the demands for change. The 21st century needs teachers who could teach primary mathematics competently. Consequently specialization at the primary level of education was introduced. Primary school teachers in Botswana are required to teach mathematics so that test scores in mathematics which are reported to be low could be improved (Republic of Botswana 2010) To improve the performance of students in mathematics at the primary level of education, there is a need to first improve teacher education programmes in mathematics education.

Studies conducted in Botswana on mathematics teacher education programmes are thin (Akinsola &Mapolelo, 2015), yet mathematics is considered as the backbone for technological and industrial developments. Research indicates that the quality of mathematics education children receive at the primary level of education lays a foundation for learning mathematics at higher levels of education (Republic of Botswana, 2015). Therefore, training pre-service primary teachers in mathematics is critical for the restoration of adequate flow of high quality mathematics students. Research indicates that interest in majoring in mathematics starts at the primary level of education (Kilpatrick, et al, 2001).

Research reports that the performance of Batswana students in mathematics is very low (TIMSS, 2007 cited in Republic of Botswana, 2010). Amongst several views attributed to this poor performance in mathematics is lack of strong foundation that children should have received at the primary level of education. It has been reported that primary teachers who hold Primary Teachers' Certificate were not competent enough to teach the current primary mathematics curriculum (Mosothwane & Nchabe, 2008). Consequently reforms were introduced in primary colleges of education. A two year certificate course was replaced by a three year Diploma in Primary Education qualification in the hope that mathematics education would be improved. However, questions have been raised concerning the quality of mathematics courses offered by primary colleges of education. The question of interest is: are pre-service teachers who major in mathematics education in primary colleges of education being taught essential concepts which can help them teach primary mathematics with confidence? In other words, are pre-service teachers being prepared for mathematics for teaching? Therefore, this study seeks to identify what pre-service teachers perceive as essential mathematics concepts which could help teachers teach primary mathematics with confidence.

Research has reported that the quality of school mathematics teachers have received depends to a large extent on the type of curricular and professional training they have received in their pre-service training programmes. In the context of Botswana, primary colleges of education offer mathematics education courses composed of two components, namely 'Academic Studies' and 'Professional Studies' (Primary Colleges of Education: Diploma Mathematics Syllabus, 1995).

The quality of a mathematics teacher is determined by the possession of the two components. A pre-service teacher who satisfies these components in his/her training is said to have met the standard for teaching mathematics in primary schools. The two components (mathematics content & pedagogy) offered by Botswana primary colleges of education are described below.

Academic Studies (Mathematics content)

This component of mathematics education provides pre-service teachers with an in depth knowledge of mathematics content. A teacher who possesses content knowledge is reported to have mastered the content and is said to be in command of what he/she teaches. Grossman, et al(1989) calls this component subject matter knowledge (SMK) and defines it as 'the amount and the organization of knowledge in the mind of the teacher. ,She goes on to say subject matter knowledge is a complex construct consisting of many facets which constitute knowledge. Therefore, for pre-service teachers to teach primary mathematics confidently, they require content knowledge to explain mathematics concepts correctly and to be able to identify misconceptions that students may possess. Lee (2000) says content knowledge

consists of an understanding of key facts, concepts, principles and explanatory frameworks in a discipline as well as values and proofs within the discipline (Grossman, et al 1989, cited iby Lee,, 2000, p.25).

Polya is of the view that content knowledge is critical for teaching and suggests that emphasis should be placed on subject matter knowledge to methods as 9:1 because without it, teaching would not be possible. This shows the importance of this component of mathematics education. Ryan and McCrae (2006) point out that lack of mathematics content knowledge may hinder the transition to pedagogical thinking. It is said that a teacher who possesses increased mathematical content knowledge is able to connect topics, explain mathematics concepts conceptually and focuses more on problem solving strategies and identification of misconceptions. Such a teacher is more likely to find out why students do not understand some mathematical concepts. NCTM (1991) says content knowledge is the breadth and depth of mathematics knowledge possessed by teachers and it is crucial because it affects both what the teacher teaches and how he/she teaches it.

Professional Studies (Pedagogy)

The essence of this component of mathematics education is to make mathematics content comprehensible to learners. In the context of Botswana Primary Colleges of Education, pre-service teachers are taught different instructional strategies that are effective in promoting learning with understanding. Professional studies popularly known as Pedagogical Content Knowledge (PCK) is the most critical component of mathematics education because it is tied to content (Schoenfield, 2006). PCK exposes pre-service teachers to what actually happens in the classroom that is how the real classroom situation is like. Schoenfiled (2006) contends that a teacher who possesses PCK has forms of knowledge that are central to mathematics teaching and are at variance with the simple notion of teaching which does not help students learn mathematics conceptually. Research studies have indicated that teachers who have mastered PCK are able to vary their instructional studies to the intellectual level of learners, give examples in mathematics that learners are familiar with (Lee, 2000). Teachers who are well trained in PCK are highly knowledgeable in mathematics content and how to teach it, in mathematics curriculum and how to interpret it and are able to implement it with maximum effort (Turnuklu & Yesildere, 2007). Such teachers aim for teaching for understanding. It is expected that by the time pre-service complete their training in mathematics education, they will be able to communicate mathematics concepts effectively during instruction.

Theoretical Framework

The Revised National Policy on Education of 1994 called for the raising of entry qualification to a minimum of COSC O Level into primary colleges of education and the extension of training to a period of three years (Republic of Botswana, 1994). The policy document goes on to say 'Teacher preparation should provide for specialization at the pre-primary , lower primary and upper primary levels with some subject specialization at the upper level--- subjects should be grouped for upper primary specialization, for example mathematics/science, humanities,--'(p.45). In line with the recommendations of the Revised National Policy on Education, primary college of education mathematics panel developed mathematics education courses for pre-service primary school teachers.

Some of the objectives of mathematics education courses offered by primary colleges of education are that student teachers will:

(a) Broaden their mathematical content knowledge

(b) Relate the mathematical concepts to the teaching of mathematics in primary schools

(c) Acquire and apply pedagogical and content knowledge effectively in primary school mathematics curriculum .methodologies such as concept learning, inquiry based teaching, etc.

Although the guidelines from Primary Colleges of Education do not indicate specific methodologies to be used in teaching primary mathematics, they however called for the use of recently introduced instructional strategies.

To improve primary mathematics education in Botswana, primary colleges of education mathematics panel developed mathematics education courses based on Shulman's (1986&1987) research studies on teacher education.

Shulman's (1986 &1987) research studies suggest that mathematics education courses should be divided into two components namely subject matter knowledge (SMK) and pedagogical content knowledge (PCK). Similarly, these two components in primary colleges of education mathematics education courses were named 'Academic Studies' (SMK) and 'Professional Studies (PCK). Within these components, are essential concepts which every pre-service teacher should be exposed to in their pre-service training In the two components (Academic and Professional Studies)which are generally perceived as essential for effective teaching, pre-service teachers, were asked to state what they perceive as essential as well as what they perceive as non-essential concepts. They were asked to give reasons why they think essential concepts should be part of their training. Furthermore, they were asked to give reasons for regarding some concepts in their mathematics education as non-essential.

It is believed that the quality of mathematics teaching could be improved when teachers have been well prepared in the two components of mathematics for teacher trainees. Schoenfield (2006) observes that no teaching can be effective if teachers have not been well trained in SMK and PCK. Research studies have demonstrated that students taught by teachers with a major or a minor in mathematics education score higher on mathematics tests than those taught by teachers without a major or minor in mathematics education (Harrell & Eddy, 20012; Harrell & Eddy, 2013). Similarly the National Commission on Education of 1993 agrees with the assertion that teachers who hold a higher qualification in mathematics education, in this case Diploma in mathematics education will have a statistically significant positive effects on children mathematics test scores (Goldhaber &Brewer , 1997). Ball etal (2008) cited by Harrell and Eddy (2012) highlights the importance of PCK as a powerful knowledge that connects teacher content knowledge with knowledge

about how students learn. According to Ball, et al (2008), possession of PCK helps teachers to package information in a way that when it is delivered it would promote understanding of content by students.

Ball etal (2008), acknowledges that PCK is divided into two types, namely knowledge of content and students (KCS) and knowledge of content and teaching (KCT). Unless teachers possess these two types of PCK, they may not be able to deliver content effectively. Ball, et al (2008) also divides SMK into two types, namely common content knowledge (CCK) and specialized content knowledge (SCK). Ball, et al (2008) asserts that the two aspects of PCK are requisites for the development of PCK.

SMK equips teachers with skills and knowledge that enable them to explain content precisely while teachers who possess PCK are able to present their lessons in a way that will promote understanding. .Botswana Education and Training Sector Strategic Plan (ETSSP) 2015-2020) calls for recent instructional strategies which are in concert with Shulman' (1986 and 1987) research studies on teacher preparation. ETSSP dismisses lecturing as an obsolete teaching strategy and calls for Group Work, Problem solving, Reflection, student /teacher interaction, student/students discussion (Republic of Botswana, 2015-2020). These methodologies are in line with the constructivist methods of teaching which are devoted to promote pedagogical content knowledge.

Purpose of the Study

The purpose of this study is three fold:

(1) To identify the subject matter/content perceived by student teachers as an essential component of their mathematics education courses.

(2) To identify the pedagogical aspects of mathematics education perceived by students as an essential component of their mathematics education courses.

(3) To assess the extent to which mathematics education courses offered by primary colleges of education prepare pre-service teachers for studying mathematics courses at the degree level.

Research Questions

(1) What subject matter/content knowledge is perceived by student teachers as an essential component of their mathematics education courses?

(2) What pedagogical aspects of mathematics education are perceived by pre-service teachers as an essential component of their mathematics education courses?

(3) To what extent are mathematics courses offered by primary colleges of education preparing pre-service teachers for studying mathematics courses at degree level?

Methodology

Description of instrumentation and Data Collection

The interview protocol instrument composed of two parts was designed for this study. Part A was on 'Academic Studies' and solicited information from pre-service teachers on what they perceive as essential component of subject matter knowledge and why they consider such concepts essential. There was a question in Part A which asked pre-service teachers to state the concepts that they think should have not been included in academic studies course. There was also a question in Part A which asked pre-service teachers if the subject matter they are taught in the Diploma in Primary (mathematics education) academic studies prepare them for studying mathematics at degree level. Part A was composed of three structured interview questions which dealt with subject matter knowledge.

Part B was on 'Professional Studies and solicited information from pre-service teachers on what they perceive as essential components of their mathematics education professional studies and why such professional studies concepts are considered essential. Part B also has a question that asked pre-service teachers to state components of professional studies which they think will not help them in teaching primary mathematics and why they think such professional studies concepts will not help them in teaching primary mathematics. Part B also has a question which asked pre-service teachers if the professional studies components adequately prepare teachers for teaching primary mathematics effectively.

Validation of the instrument

The instrument was given two mathematics educators, one at the examination council and the other in department of research in the Ministry of Education, and Skills Development to check for clarity, ambiguity, omissions. After constructive suggestions were made, the validators confirmed that the instrument actually measures teachers' perceptions of two constructs namely 'Academic and 'Professional Studies'.

Participants

The instrument was then administered to eleven third year pre-service teachers. The interview lasted for four hours for each participant, two hours for 'Academic Studies and two hours for 'Professional Studies'.

The Results

The results of the study are presented below in themes and are supported by direct quotes.   The responses are answers to interview questions. P1 through P11 stands for pre-service teachers 1 through 11.

Theme 1: Mathematics Content Knowledge

Interview Question 1: What mathematical content concepts do you think are essential components of your mathematics education courses and why do you think they are essential?

P1: They are many, statistics, matrices, vectors, trigonometry, sequences and series, geometry, calculus Statistics provide information on weather activities, on prices of good, etc.; Statistics is also in the primary school mathematics syllabus. Matrices help us to write large information into manageable form.

P2: Vectors help us in teaching direction. Series and sequences teach us number patterns. They challenge our thinking processes. Functions are also essential content topics in mathematics education. Functions show a relationship between two things. Functions sharpen our thinking capacity, especially when calculating domains, ranges and inverses.

P3: Trigonometry is used when bridges are constructed, yah it helps engineers to use correct angles and others. Trigonometry helps us to solve real life problems.

P4: Probability. Probability helps us to predict weather conditions. It helps scientists to take chance! Probability promotes problem solving skills; it sharpens our thinking processes as well.

Theme 2: Non-essential mathematics content

Interview Question 2: Are there other topics in the 'academic studies syllabus that you think are not an essential component of your mathematics education courses?

P9: Yes. Civic arithmetic, it's really boring. It's not exciting and it does not help us to acquire new knowledge. History of mathematics, Egyptians, Babylonians, the Greeks. I don't see how this topic is related to the teaching of mathematics. I do not see their applications to primary mathematics teaching. At the moment they are taught not in relation to mathematics teaching.

Theme 3: Essential mathematics concepts in professional studies

Interview Question 3. Are there concepts that you consider essential in your professional studies?

P6: Yes, there are many concepts or rather topics. Psychology of learning mathematics, we are taught how children learn mathematics. We now know that every child has his/her learning style and we have to encourage them to use their learning styles. Each child understands mathematics better when using his/her own learning style.

Theme 4:Non-essential concepts/ topics in professional studies

Interview Questions: Are there concepts/topics in your professional studies course that you think are not essential in the teaching of primary mathematics? Support your answer.

P7: Yes, beliefs and attitudes. I do not know how essential they are in the teaching and learning of primary mathematics. The way they are taught is disconnected from the teaching and learning of primary mathematics. Their role in the teaching and learning is not shown, as of now we do not see their relevance. Another non-essential concept is contemporary issues in mathematics.

P9: We do not see how this topic is related to mathematics, teaching. I think if examples that we are familiar with are used, it would make sense to us. Let us take an example of AIDS as a contemporary issue, I think AIDS in mathematics is related to the teaching of statistics and the information is presented in bar charts, histogram, and pie charts. We need someone who could explain contemporary issues relating them to the teaching and learning of mathematics in primary schools.

P10: Modelling is not an essential concept in primary mathematics. We do not model concepts in primary mathematics. I do not see the connection. We need someone who can teach it in a meaningful way so that it is related to the teaching of primary mathematics.

P11: Another non-essential topic in our mathematics course is Mathematics and culture. This is one of the topics that do not make any connection to mathematics teaching. If this topic was taught related to the teaching and learning of mathematics, we would value it, as it is now, it is divorced from the teaching and learning of primary mathematics.

Theme 5: Mathematics content preparing pre-service teachers for university mathematics

Interview Question 5: Does the mathematics content being taught in Primary Colleges of Education prepare you to study mathematics at the University Level.

P3: I think it prepares us for university mathematics courses. We are taught Algebra, Geometry, Trigonometry, Statistics and calculus.

P4: No, I disagree, the mathematics content that we are taught is at the junior and senior secondary school levels of education. Simultaneously equations, quadratic equations, factorization are taught at the secondary school level of education but we still do them in the Diploma Courses.

P5: They used to teach Calculus, but they have now excluded Integral Calculus from our Academic Studies course. They only teach introduction to differential calculus. So we are deficient in mathematics content and we will find it hard to study mathematics at the university level.

P9: No, it does not. How can we say we have been prepared for university mathematics when our math courses are below the courses offered at Junior Secondary Colleges of Education? It does not make sense. Mathematics education courses offered at Junior Secondary Colleges of Education are much higher than those offered at Primary Colleges of Education.

P2: Yah, I think we will struggle when we do mathematics at the university level. I do not think mathematics courses we are doing prepares us for university mathematics courses. There is a need to review mathematics courses offered in Primary Colleges of Education. Our mathematics courses need to be reviewed so that it is at par with mathematics courses offered in Junior Secondary Colleges of Education.

P11: No, the content we are being taught does not prepare us for university mathematics. It is of very low standard and needs thorough review.

Discussion of the findings

Primary Colleges of Education in Botswana have guidelines for preparing pre-service mathematics teachers for primary schools. Primary Colleges of Education (PCOE) clearly state in their guidelines the knowledge base that pre-service teachers must master in their pre-service training (Tlokweng College of Education, Department of Mathematics: Years 1, 2 and 3 Course Outlines, Academic Year 2016/2017). This is critical because preparation of primary school mathematics teachers is the foundation upon which further learning in mathematics will be based. Once that foundation is not strong, children will have a mathematics phobia even in higher grades/standards. Bibby (1986) cites a student's reaction to mathematics as follows 'It reminded her of a boa constrictor which slobbers its victims before swallowing' (p.60; cited by Arvidson, 2009, in Training Elementary Teachers of Mathematics: What are the essential components? p.1). This indicates that children who have mathematics phobia may think of mathematics as something that kills and this may also create an impression that mathematics is not for everybody, but for the few privileged ones..

The aim of mathematics programme for primary school teachers is to produce good mathematics teachers who not only know their content but also know things about their content that makes effective instruction possible (McDiarmid, Ball and Anderson, 1989).

Although primary colleges of education offer both academic and professional studies, the responses of pre-service teachers suggest that what primary college mathematics educators perceive as essential mathematics concepts in mathematics education is not what pre-service mathematics teachers perceive as essential mathematic education concepts. This suggests that there is a lack of consensus about what mathematical concepts pre-service teachers need to know in mathematics education courses (Davis and Simmt, 2006). However, it is generally known that primary teachers need to know mathematics for teaching.

The essence of academic and professional studies is to strike a balance between subject matter knowledge and pedagogical content knowledge. The results of the study, however, suggest that pre-service teachers perceive subject matter knowledge (SMK) as more essential than pedagogical content knowledge (PCK). However, research points in a different direction when suggesting that more emphasis on content may be inappropriate (Ball, et al, 2001). This was also observed by Freudenthal in 1973 when he says 'It might be that teachers require more nuanced understanding of the topics in a conventional curriculum' rather than more content (cited by Davis and Simmt, 2006, p, 294). Research studies in mathematics education underpin the importance of nuanced understanding as follows:

Teachers must be adept at interpreting concepts for learners. This competence requires knowledge of how mathematics topics are connected, how ideas anticipate each other, and what constitutes a valid mathematical argument (Davis and Simmt, 2006, p. 295).

One of the complaints raised by pre-service teachers is that the mathematics content that is taught in primary colleges of education is of the lower standard. This complaint seems to be justified as our experience at the University of Botswana, Department of Primary Education is that in-service primary school mathematics teachers who enter year 3 terribly struggle to grasp mathematics concepts they are expected to have covered at the Diploma level of education. Hence, it may well be concluded that mathematics courses offered by PCOE do not prepare pre-service teachers for university mathematics courses.

In an effort to improve the quality of mathematics education in PCOE, primary college mathematics educators, should collaborate on course designs with university mathematics educators so that what is taught in PCOE is dynamic forward looking and collaborate human endeavours. This has happened in Australia (NSW, Department of Education and Training, 1997). A strong relationship between primary college mathematics educators and university mathematics educators must be established to ensure that pre-service teachers' mathematical knowledge and skills are kept up to date.

Some topics/concepts which pre-service teachers perceive as non-essential such as history of mathematics, mathematics and culture to name a few are internationally regarded as essential concepts. Pre-service teachers reported that they do not see the relationship between these topics/concepts and what is taught in primary mathematics. History of mathematics plays a critical role in prompting understanding of some mathematics topics, for example Geometry. However, the conclusion drawn from pre-service teachers responses suggest that History of mathematics is taught entirely divorced from its application in mathematics. A workshop on History of mathematics is urgently needed to ensure that PCOE mathematics educators do not divorce it from school mathematics.

While pre-service teachers do not regard mathematics and culture as essential, research studies in mathematics education suggest that mathematics and culture are a requisite for mathematics teacher education because its discourses are based on the language of mathematics.(Bailey and Taylor, 2010). The results of the study suggest that pre-service teachers have not yet grasped a fundamental understanding of mathematics as they do not see the relevance of culture to mathematics teaching.

It is suggested that a mathematics teacher who does not have an understanding of mathematics and culture may not be effective in promoting understanding of mathematics concepts/topics. This is because a group of primary mathematics teachers constitutes a cultural group. Therefore the language that they use in teaching mathematics is the culture of mathematics teachers. As Snipes and Moses (2015) noted, ---cultural groups are not limited to just racial and ethnic groups. Examples of cultural groups include high school mathematics teachers, accountants, and computer scientists to name a few. All these groups have their own language, traditions, and ways of interpreting and conceptualizing situations' (p.1).

It is believed that culture is important because primary school teachers who hold Diploma in Primary Mathematics will use the right language of mathematics that will help to promote students' understanding of mathematics. As a result these teachers will have statistically significant positive effects on primary school children's performance in mathematics test scores. This may curb the Government's concern that the scores in mathematics continue to decline nationwide.

Implications for teacher education programme

It is now over twenty years ago when the training of primary pre-service teachers in mathematics education in Primary Colleges of Education was raised to Diploma level. The intention was to raise the standard of mathematics education in Botswana, however, the performance of primary school children continues to decline despite high teacher qualification.

This has implications for teacher education programme in mathematics education offered by PCOE. First PCOE must review their mathematics education courses to ensure that pre-service teachers complete their training with an understanding of the centrality mathematics content for teaching and how content knowledge is effectively delivered to students (Grossman, et al, 1989).

Grossman, Wilson & Shulman (1989) gave advice on teacher preparation as follows:

> Instead of thinking about learning to teach as a process through which one learns about pedagogy alone, learning to teach must be conceptualized as both learning more about subject matter and learning how to communicate that knowledge effectively to many kinds of students (pp; 21-22).

What this implies is that teaching pre-service teachers should not only put more emphasis on pedagogy alone, but rather on conceptual understanding. My experience as a teacher educator in the late 1970s is that Teacher Training Colleges (TTCs) in Botswana put more emphasis on pedagogy rather than PCK which embraces both pedagogy and subject matter.

Arvidson (2011 observes 'most of mathematics children know is learned in school and depends on the capabilities and knowledge of their classroom teachers (p.7). This implies that PCOE must train pre-service teachers adequately in both subject matter knowledge and PCK since children's mathematical knowledge depends entirely on teachers. The essence of mathematics education courses in PCOE should provide pre-service teachers with 'an opportunity to look deeply at fundamental ideas of mathematics, to connect topics which students often see as unrelated and to develop the important mathematical habits of mind (CBS, 2001 cited by Harrell & Eddy, 2015). What CBS is advocating for is missing from mathematics education courses offered by PCOE. This is shown by the responses of pre-service teachers when they stated that they see no relationship between mathematics content, mathematics and culture, and contemporary issues in mathematics. It appears college lecturers lack skills and competencies which they need for effective instruction and for connecting mathematical ideas to everyday life activities. The responses of pre-service teachers to interview questions tend to support the above assumption.

Conclusion

The quality of teaching depends on the training that teachers have received in their pre-service courses. Consequently, pre-service teachers must develop the ability to acquire new knowledge which shows the connection between different aspects of mathematical content knowledge. As revealed by pre-service teachers' responses to interview questions, it cannot be concluded that pre-service teachers possess competent skills for teaching mathematics relationally. Lack of

such skills could lead to children's decline in mathematics test scores. Pre-service must acquire in their training knowledge related to other types of subject matter knowledge which would help them to teach mathematics relationally when they graduate. As it is now, it appears they would graduate being deficient in relational learning (Skemp, 1979).

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