

## TEACHERS' CONTENT AND PEDAGOGICAL KNOWLEDGE ON STUDENTS' ACHIEVEMENT IN ALGEBRA

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### **Abstract**

*The paper focuses on teachers' content and pedagogical content knowledge on students' achievement in algebra. Using a test re-test quasi- experimental design with a 3x3x2x2 factorial matrix, the researchers purposively sampled 421 senior secondary school II students and 12 mathematics teachers from eight (8) public and four (4) private schools in Education District 5 of Lagos State. The three instruments used are TCTA, OSTP and SATA. OSTP has Spearman' rho reliability coefficient of 0.77, while the TCTA and SATA produced reliabilities of 0.79 and 0.81 respectively using the Gutman' split half reliability method. The three instruments developed were validated and used for data collection. Data were analysed using graphs and ANCOVA. The results  $F(2, 387) = 0.56; p = 0.67$  revealed that all categories of the subject were equally affected by TCK in algebraic achievement after exposure to teacher' content knowledge. However,  $F(2, 387) = 12.91; p = 0.00$  indicated that students were not equally affected by TPK in algebraic achievement test. On the other hand,  $F(1, 387) = 0.11; p = 0.90$  indicated that gender has no significant effect on students' achievement in algebra after exposure to teachers' content and pedagogic knowledge. Furthermore,  $F(1, 387) = 0.21; p = 0.81$  showed that school type has no significant effect on students' achievement in algebra after exposure to teacher' content and pedagogic knowledge. Also,  $F(1, 387) = 0.90; p = 0.34$  revealed no significant interaction effect of content and pedagogical knowledge, gender and school type on students' achievement in algebra. In view of the findings, the study recommends that teachers of Mathematics, with in-depth knowledge of the subject and well groomed in teaching pedagogy should be allowed to teach algebra in schools.*

**Keywords:** Teachers Content knowledge, Pedagogy content knowledge, students' achievement and Algebra

## 1. INTRODUCTION

In recent years, discuss on teachers' content knowledge (TCK) and teachers pedagogy knowledge (TPK) has attracted increasing attention from several agents of change in education industry. It is well known fact that any nation whose government strive to achieve greatness should provide students with highly qualified teachers who are vast in content knowledge and pedagogical knowledge, ethics or other means. Evidences available from researches suggest that teachers' intellectual resources significantly affect students' learning experiences (Odumosu, Olusesan and Abel, 2016) and this has made educators to focus on the knowledge of the subject matter because researches suggest that teachers of mathematics lack essential content knowledge for teaching the subject Ma, (1999), Olfos, Goldrine and Estrella (2014).

Researches also show that students record the most gains when assigned effective teachers in term of content knowledge Ogar (2006). Indeed, such findings have led many researchers and analysts to assert that lack of effective teachers is a major contributory factor in the performance gap among students.

The primary purpose of teaching at any level of education is to bring a fundamental change in the learner (Tebabal & Kahssay, 2011). In order to achieve this, it is expected that a mathematics teacher should have the knowledge and a high level of understanding of the concept "Algebra" which is one of the areas in mathematics which students found difficult to pass (Ladele, 2013). Many studies supported the notion that teachers who taught the subjects that they had previously studied in-depth are particularly effective (Olisama, Odumosu and Egho, 2011). There is therefore strong indication that there is high correlation between teachers' content knowledge and students' performance in Mathematics in general and Algebra in particular.

A growing body of research shows that students' performance is more heavily influenced by the teacher's quality in terms of content knowledge and pedagogy knowledge than by students' priors academic record or school a student attends Ishola and Udofi (2017). Researches indicate that the performance gap widens each year between students with most effective teachers and those with least effective teachers Ogar (2006). The implication is that the most significant gains in students' performance will likely be realized when students receive instruction from good or effective teachers over consecutive years. This is very important in the teaching of Mathematics which is cumulative in nature.

Several studies report that teachers' content knowledge influences students' performance in mathematics (Wayne and Youngs, 2003). In another study, Rio de Janeiro (19) found a positive relationship between social economic class of the students and teachers content knowledge. Resently, the Nigerian secondary school students' mathematics performance still remain poor, it appears that "the implemented curriculum is at variance with the intended curriculum" National Council of Teachers of Mathematics (NCTM), (2000). There in need to examine the content knowledge of the teacher vis-a-vis the students' performance in algebra. Another important variable that can affect students' performance in mathematics is pedagogy. The science of teaching is referred to as pedagogy (Ogunboyede, 2011) while McCaughtry (2005) and Sidhu, Fook and Kaur (2011) stressed that pedagogical content knowledge refers to teaching and learning of the subject. Several studies in the area of mathematics have shown that pedagogical content knowledge, especially at senior secondary school level remains overwhelmingly teacher-centered with greater emphasis being placed on lecturing and textbook than on helping students think critically across subject area and applying their knowledge to real world situations (Butty, 2001). In some instances, analyses of pedagogical content knowledge for teaching have posted many challenges for mathematics teachers in various dimensions for example knowledge for teaching versus knowledge for oneself (Borko, 2002) and lesson structure knowledge versus subject matter knowledge

(Leinhardt, 2005) and also knowledge for teaching mathematics (Brousseau's, 2007). Since, high value is placed on mathematics at the Nigerian Senior Secondary School Curriculum, the nature of the subject, the need to have thorough content knowledge in algebra and ability to teach it effectively are major concern of mathematics educators. There is therefore the need to examine pedagogy being used by the teachers of mathematics. Pedagogical content knowledge in this study connotes knowledge of subject, knowledge of teaching and knowledge of curriculum.

It is evidently clear from literature that gender is another learner characteristic that has been shown to exert considerable influence on students' learning outcomes especially in mathematics which has been seen as male dominated. Gender differences in educational outcomes are well known phenomena (Ifamuyiwa , 2002). Abundant evidence in literature shows that sex is a strong predictor of human conduct and a determining factor in students' achievement.

Research studies show that the type of school a student attends can also contribute to his or her performance in mathematics Odumosu, Olusesan and Abel (2016) while other studies have attributed factors ranging from socio-economic background, intelligence, attitude of students to the subject-matter, the incidence of unfriendly relationship between mathematics teachers and students too have attributed to poor performance of students in Mathematics in general and algebra in particular Ogunboyede, (2011). Several studies have been carried out in mathematics content area (Hill, Schilling & Ball, 2004), (Rowan, Corrent & Muller, 2002), (Rowan, Schilling, Ball, Miller & Atkins-Burbett, 2001), (Ball, Lubienski & Mewborn, 2001) and (Ball, & Bass, 2000). However, no one has been carried out in algebra, and also research is not yet clear about the magnitude of the effect of teachers' content knowledge and pedagogical knowledge relative to gender issue and school type on students' performance in algebra.

This study therefore is set out to find the effect of teachers' content and pedagogical knowledge on students' academic achievement in Algebra, relative to gender and school type at Senior Secondary Schools in Education District V of Lagos State.

The purpose of this study was to encourage aspiring mathematics teachers to embrace the idea of studying mathematics in-depth in tertiary institutions as well as to encourage them to be vast in problem solving techniques and other pedagogies that will bring about effective learning of algebra in secondary schools and also encourage in-service teachers to attend conferences and workshops or short courses or apply for a part-time study in mathematics if need be, to enhance their teaching pedagogy.

## **2. RESEARCH QUESTIONS**

The following research questions were raised to guide the study.

- (i). What are the effects of TCK on students' academic achievement in algebra?
- (ii). What are the effects of TPK on students' academic achievement in algebra?
- (iii). Do TCK and TPK have any effect on students' academic achievement in algebra based on gender?
- (iv). Do TCK and TPK have any effect on students' academic achievement in algebra based on school type?

## **3. RESEARCH HYPOTHESES**

The following null hypotheses were tested at 0.05 significant level.

**H<sub>01</sub>:** There is no significant effect of i) TCK and ii) TPK on students' academic achievement in Algebra.

**H<sub>02</sub>:** There is no significant effect of i) TCK and ii) TPK, on students' academic achievement in Algebra based on gender.

**H0<sub>3</sub>:** There is no significant effect of i) TCK and ii) TPK, on students' academic achievement in Algebra based on school type.

**H0<sub>4</sub>:** There is no significant interaction effect of TCK, TPK, students' gender and school type on students' academic achievement in Algebra.

#### 4. RESEARCH METHOD

##### Design

This study adopted the pretest, posttest quasi experimental design involving a 3x3x2x2 factorial matrix. Students achievement level was determined by cross-tabulating teachers content knowledge (high, average and low) and pedagogy content knowledge (high, average and low) with school type (public and private) and gender (male and female) on students' academic achievement.

##### Participants in the study

The participants for this study comprised 421 Senior Secondary School II (SS 2) students drawn from twelve (12) Senior Secondary Schools in Education District V of Lagos State using simple random sampling. The subjects are made up of 195 male and 236 female students constituting 268 students from public schools and 153 students from private schools and 12 teachers (8 from public and 4 from private). The teachers were selected using purposive and proportional sampling techniques and grouped into three ability levels namely high, average and low respectively according to their content and pedagogical knowledge. Among the selected teachers are four (4) with high, six (6) average and two (2) low content knowledge and pedagogical knowledge respectively of which one (1), two (2) and one (1) are private school teachers.

The choice of SS 2 students was considered more appropriate because these students were already exposed to some basic Mathematics concepts and skills such as solving simple equations, factorisation and expansion of algebraic processes, substitution and elimination, completing the square, and solving word problems from basic 7 to Senior Secondary School 1. Thorough understanding of which will enhance their problems solving on quadratic equations and simultaneous equations in Algebraic Processes. The students were taught in their first term of SS 2, by the selected teachers.

##### Research Instruments

Three research instruments used in data collection are:

- I. Teachers' Content Knowledge Test in Algebra (TCTA).
- II. Observational Schedule of Teachers' Pedagogy Knowledge (OSTP).
- III. Students' Achievement Test in Algebra (SATA),

Fifty (50) item of open answer questions TCTA consisting of knowledge on quadratic equations and simultaneous equations, drawn from the Senior Secondary School Curriculum was given to teachers to obtain their content knowledge on the topics. OSTP was used to determine the pedagogy knowledge of the teachers. The results obtained from these instruments were used to determine the level of the teacher content knowledge namely high, average and low. The SATA, a 50-item multiple choice on quadratic equations and simultaneous equations achievement test with four options per item was used to determine the effect of the 3 categories of teachers on students academic achievement in Algebraic processes. The TCTA and OSTP were obtained for each teacher and analyzed using (75th percentile, 50th percentile and 25th percentile) for teachers with high, average and low content and pedagogy knowledge respectively. The validation of the observation scheduled and test instruments were ascertained by giving to three (3) experts in Mathematics Education for face validity. The OSTP yielded a Spearman's rho reliability coefficient

of 0.77, while the TCTA and SATA produced reliability of 0.79 and 0.81 respectively using the Gutman’ split half reliability method. Teaching of selected content took twelve (12) weeks of three to four periods of 40 minutes per week as contained in the scheme of work for SS 2 classes. Each teacher was free to write his/her notes of lessons and identify pedagogies to be used based on the curriculum requirements. It was observed that 80% of the teachers combined problem solving method with other methods.

**Data Collection Procedure**

The research procedure involves training three research assistants for one week on the observation schedule. The participating teachers were examined and grouped based on their performance on content knowledge and pedagogy knowledge. The trial tests on the instruments were carried out using 3 teachers and 20 students. The three research assistants were asked to rate the participating teachers (using observation schedule prepared by the researchers) during the trial practice. The exercise produced inter-rating reliability values of between 0.79 and 0.82 range. The second week of the term was used for pre-test. The researchers with the help of participating teachers administered the pre-test SATA to the participating students to test their entry level. The post test was administered after the learning activities took place for twelve weeks in each selected school.

**Data Analysis Procedure**

Graphs were used to explain the effect of teachers ability and pedagogical knowledge on students’ post test achievement. Analysis of covariance (ANCOVA) was used to analyse effect of TCK and PCK on students’ achievement based on school type and gender.

**5. FINDINGS**

The findings are given below:

**Research Question 1:** What are the effects of TCK on students’ academic achievement in algebra?

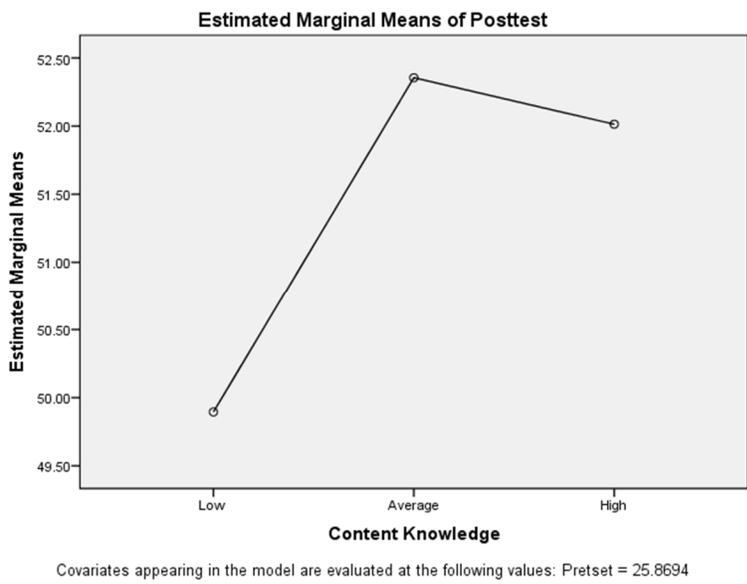


Fig 1: Effects of TCK on Students’ Achievement in Algebra

The result in Fig 1 shows that teachers with low, average and high TCK levels produced students with marginal mean scores of 50%, 53% and 52% respectively.

**Research Question 2.** What are the effects of TPK on students’ achievement in algebra?

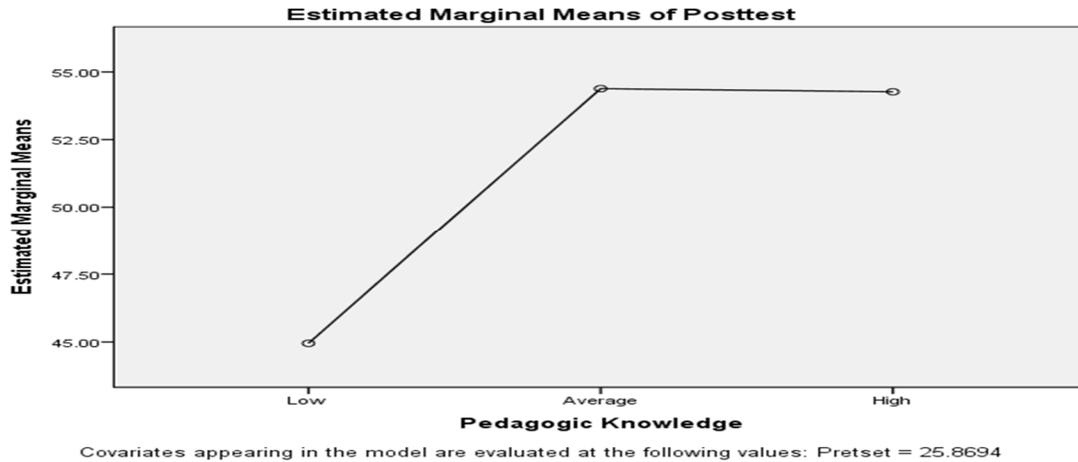


Fig 2: Effects of TPK on Students’ Achievement in Algebra

The result in Fig 2 shows that teachers with low, average and high TPK levels produced students with marginal mean scores of 45%, 55% and 55% respectively.

**Research Question 3.** Do TCK and TPK have any effect on students’ academic achievement in algebra based on gender?

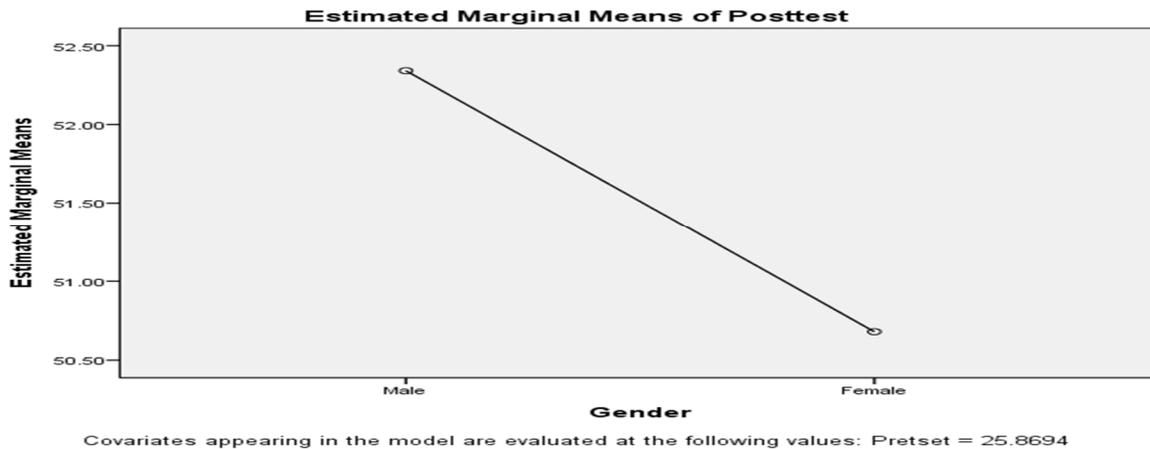
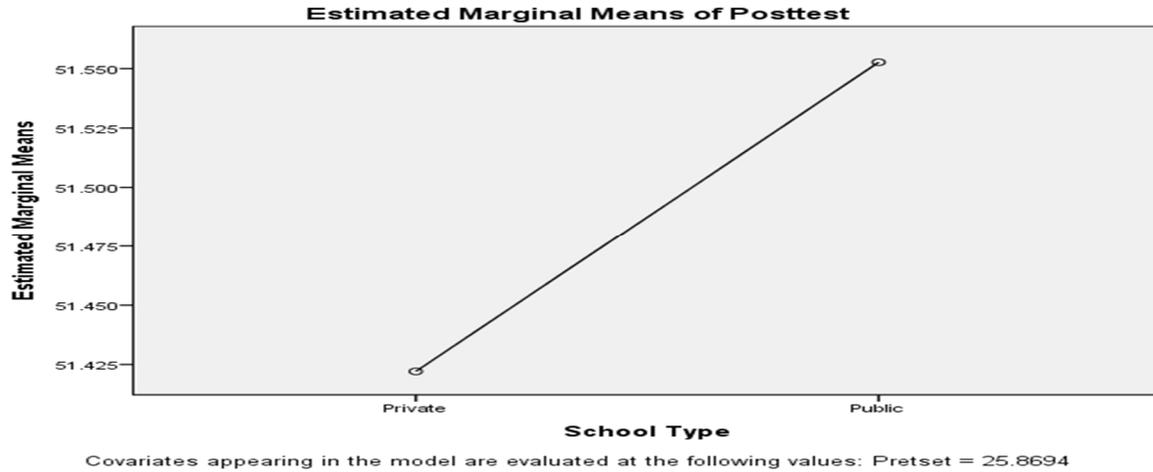


Fig 3: Effects of Gender on Students’ Achievement in Algebra

The result in Fig 3 shows that male students obtained a marginal mean score of 53% while the females scored 51%.

**Research Question 4.** Do TCK and TPK have any effect on students’ academic achievement in algebra based on school type?



**Fig 4:** Effects of School Type on Students’ Achievement in Algebra

The result in Fig 4 shows that students in private schools scored 51% while those in public schools scored 52%.

**H0<sub>1</sub>:** There is no significant effect of i) TCK and ii) TPK on students’ academic achievement in Algebra.

**Table 1:** Showing pre-test results and effects of TCK and PCK on the subjects.

Tests of Between-Subjects Effects					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4946.771 <sup>a</sup>	33	149.902	2.550	.000
Intercept	15269.081	1	15269.081	259.694	.000
Pretest	39.406	1	39.406	.670	.413
Gender	65.703	1	65.703	1.117	.291
SchType	4.840	1	4.840	.082	.774
TCK	66.062	2	33.031	.562	.571
TPK	1518.533	2	759.266	12.913	.000
Error	22754.179	387	58.796		
Total	1272569.000	421			
Corrected Total	27700.950	420			

The result  $F(1, 387) = 0.67$ ;  $p = 0.41$  and  $F(1,387) = 1.117$ ;  $P= 0.29$  of the pre-test show that the students differ insignificantly in academic achievement in algebra irrespective of gender and school type before exposure to teacher’ content and pedagogic knowledge. This means that the students achieved equally before they were taught by teachers with high, average and low TCK and TPK.

Also, the result  $F(2, 387) = 0.56$ ;  $p = 0.57$  is an evidence that the students differ insignificantly in academic achievement in algebra irrespective of the teachers’ content knowledge. This means that the students were equally affected by TCK.

However, the result  $F(2, 387) = 12.91$ ;  $p = 0.00$  shows that the students differ significantly in academic achievement in algebra when taught by teachers’ with three levels of pedagogy content knowledge. This means that the students were not equally affected by TPK. The students taught by

teachers with low pedagogy content knowledge performed lower than those taught by high and average pedagogy content knowledge. Therefore, the second part of this null hypothesis was rejected.

**H0<sub>2</sub>:** There is no significant effect of TCK and TPK, on students' academic achievement in algebra based on gender.

**Table2:** Showing effects of TCK and PCK on the subjects based on gender.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Gender * SchType	4.071	1	4.071	.069	.793
Gender * TCK	38.617	2	19.309	.328	.720
Gender * TPK	12.989	2	6.495	.110	.895
Error	22754.179	387	58.796		
Total	1272569.000	421			
Corrected Total	27700.950	420			

The results  $F(1, 387) = 0.33$ ;  $p = 0.72$  and  $F(1, 387) = 0.11$ ;  $p = 0.90$  indicate that the students differ insignificantly in academic achievement in algebra based on gender after exposure to teachers' ability levels of content knowledge and pedagogy knowledge. This means that gender has no significant effect on students' achievement in algebra.

**H0<sub>3</sub>:** There is no significant effect of TCK and TPK on students' academic achievement in algebra based on school type.

**Table 3:** Showing effects of TCK and PCK on the subjects based on school type.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Gender * SchType	4.071	1	4.071	.069	.793
SchType * TCK	24.961	2	12.481	.212	.809
SchType * TPK	31.144	2	15.572	.265	.767
TCK * TPK	162.403	4	40.601	.691	.599
Error	22754.179	387	58.796		
Total	1272569.000	421			
Corrected Total	27700.950	420			

Table 3 shows  $F(1, 387) = 0.21$ ;  $p = 0.81$  and  $F(1, 387) = 0.27$ ;  $p = 0.77$  that the students also differ insignificantly in algebraic achievement by school type after exposure to teacher' content and pedagogy knowledge. This also implies that school type has no significant effect on students' achievement in algebra.

**H0<sub>4</sub>:** There is no significant interaction effect of mathematics teachers' content knowledge, pedagogic knowledge, students' gender and school type on students' academic achievement in algebra.

Table 4: Showing interaction effect of TCK, PCK, gender and school type on the subjects.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Gender * SchType * TCK	92.386	2	46.193	.786	.457
Gender * SchType * TPK	137.985	2	68.992	1.173	.310
Gender * TCK * TPK	67.043	4	16.761	.285	.888
SchType * TCK * TPK	206.065	4	51.516	.876	.478
Gender * SchType * TCK * TPK	52.782	1	52.782	.898	.344
Error	22754.179	387	58.796		
Total	1272569.000	421			
Corrected Total	27700.950	420			

a. R Squared = .179 (Adjusted R Squared = .109)

The result  $F(1, 387) = 0.90$ ;  $p = 0.34$  reveals no significant interaction effects of gender, school type, content and pedagogy knowledge on students' achievement in algebra. This implies that there was no interaction effect of students' academic achievement in algebra based on TCK, TPK, students' gender and school type. The null hypothesis was not rejected.

## 6. DISCUSSION

The finding revealed that there is no significant effect of mathematics teachers' content knowledge on students' academic achievement in algebra. This may not be unconnected with the high number of students' (91%) taught by teachers' with high and average content knowledge. Similarly, a large percentage of students (92%) taught by teachers with high and average pedagogy knowledge may account for no interaction effect of dependent variable. The implication is that Mathematics teachers have high and average content knowledge and this has translated to students having relatively good performance in algebra. The high content knowledge of the teachers might be because they were exposed to advanced level algebra in their undergraduate days which could have contributed to high score of teachers' content knowledge in algebra. Also, the curriculum of the teachers' education at Colleges of Education or Universities now contains more advanced courses in mathematics education than in recent past. This may account for high content knowledge of mathematics teachers in Algebra. Another reason may be that the teachers rated high and average in content knowledge delivered their lessons excellently. This result corroborates the findings of (Festus, 2008) which states that if students are taught by teachers of high content knowledge they perform better and this has shown even in the students' performance in algebra. Collaborating this assertion are Olfos, Goldrine and Estrella (2014) and Popoola (2002) who found a strong correlation between teachers' pedagogical content knowledge and students' understanding in learning.

Though, algebra is an important part of school mathematics but sometimes it poses challenges for students to learn because of letters involved and somehow its abstract nature (Ladele, 2013). However, when taught by teachers with good content knowledge the challenges can be surmountable or minimized. In contrast, Darling-Hammond (2000) reported that students' performance depends on measurable teacher attributes such as verbal ability, content knowledge and certification among other variables.

The study is also in consonant with the works of Ishola and Udofia (2017); Ogar (2006) who affirmed that teachers' mastery of the subject matter is a component that determines the extent of students learning and achievement. Contents determine the quality of learning activities and thus a teacher with good mastery of the subject area is characterized to have good knowledge of classroom

management, use adequately learning materials, maintaining clarity of thought, bold and confident of what he wants to teach and teach effectively and efficiently.

The study further revealed that the students differ significantly in academic achievement in algebra when taught by teachers' with three levels of pedagogy content knowledge. This means that the students were not equally affected by teachers' pedagogical knowledge. The students taught by teachers with low pedagogical content knowledge performed lower than those taught by high and average pedagogy content knowledge. Therefore, the second part of the first null hypothesis was rejected. Pedagogical knowledge has important role to play in academic achievement of students in algebra. It is imperative therefore, that teachers of mathematics must have both the message and also the medium. This result corroborates Ogunboyede (2014) who indicates that effective classroom teaching enhances students' performance in mathematics.

Perhaps, the length of practical teaching which used to be three terms (first, Second and third) has been reduced to two terms (18 weeks) at a stretch (first and part of second term) for Colleges of Education while for Universities practical teaching comes up at the third and four year for 6 weeks each might account for this. Another issue in the teaching and learning of algebra is the unwillingness of teachers to study Mathematics at tertiary institutions, such that majority of those who studied mathematics are forced to offer the course since the institution would have filled their quota in course of choice of the candidates. The candidates are then left with no choice expect to study mathematics.

Futhermore, Gender has no effect on the academic achievement of the students, though male students had a higher average (53%) than their female counterpart with (51%). The implication is that students' achievement does not depend on gender, both male and female recorded gains in their academic achievements when taught by teachers with high content knowledge and high pedagogical content knowledge. The non-significant effect of gender conforms to Popoola (2002) and Ojo (2003) but at variance with Odumosu and Akudo (2017), Wiest (2002) and Fennema (2000) who found that male students performed better than their female counterpart when exposed to problem solving in mathematics classroom.

Also, the results revealed there was no significant difference in the achievement of students in algebra based on school type. Though, the public school students have slightly higher marginal mean of 52 as against the private school students with marginal mean of 51. The probable reason may be, the teachers have high content knowledge and high pedagogical knowledge. The implication is that no matter the type of school one attends the teachers' content knowledge and pedagogical knowledge have great impact on students' academic achievement. The public as well as private school owners should ensure their mathematics teachers are well groomed in the methodology and have good content knowledge in mathematics. The result gives an unequivocal support earlier studies by Odumosu and Akudo (2017).

## 7. CONCLUSION

The quality of mathematics teachers especially at the senior secondary education level cannot be compromised. The teachers at this level must have both the message and the medium, because the shallow knowledge of teachers in mathematics content especially in algebra will not give the desired results. If our goal is to encourage students to develop interest in Algebra in particular and Mathematics in general, this can only happen if teachers have good content know ledge and pedagogical content knowledge of mathematics (algebra) which might result in good performance of students in algebra.

## 8. RECOMMENDATIONS

Based on the results obtained, the following recommendations were made:

1. Teachers of mathematics should be exposed to various teaching strategies on algebra to boost students' performance.
2. Teachers of Mathematics should have good content knowledge of the subject and be ready to learn different strategies in teaching algebra effectively and efficiently.

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