Relationship between teachers knowledge for teaching and students achievement in algebra in some selected senior high schools in Ghana

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ABSTRACT

Core mathematics is a compulsory subject for all Senior High School students in Ghana and many other African countries. Students are expected to pass in this subject before moving on to any tertiary institution. In spite of the compulsory nature of the subject, underachievement of students in mathematics at the Senior High School level has been a matter of concern to the West African Examination Chief Examiner over the years. Though available literature is replete with factors such as pupil-teacher ratio, socio-economic status of students, class size, family background that account for students' achievement, it is clear that the success of many students depends on the teacher. It is however unclear which aspect of the teacher is statistically significant predictor of what students learn. This paper focuses on the extent to which teachers' knowledge for teaching correlates with students' achievement in algebra at the Senior High School level in Ghana. In all, 17 Elective Mathematics teachers and 617 form Three Elective Mathematics students from ten public Senior High Schools in the Central Region of Ghana participated in the study. The samples were selected at random from four school categories; A, B, C and D according to Ghana Education Service classification. Two forms of instruments were administered; form one to students and form two to teachers, and the responses retrieved on the same day. A correlational analysis was used to test for statistical significance in the scores at 0.05 level of significance. Teachers' knowledge for teaching was found to be significantly related to students' achievement in algebra.

Introduction

Studies show that schools can make a difference in students' learning and a substantial portion of that difference is attributed to teachers (Darling-Hammond, 1999; Yara, 2009). It can be said that the teacher is the most indispensable factor in the effectiveness of any educational enterprise who interacts directly with the learner (Clarke & Peterson, 1986).

"It is the teacher's competence, ability, resourcefulness and ingenuity to efficiently utilize the appropriate language, methodology and available instructional materials to bring out the best from learners in terms of academic achievement" (Yara, 2009, p.365). Yara argued that to some extent the characteristics of the teachers and their experiences and behaviours in the classroom contribute to the learning environment of their students which in turn will have an effect on students' output. In short, how teachers teach mathematics has a direct and significant impact upon how students learn and acquire new skills and information (Mullens, Murnane & Willett, 1996; Sanders & River, 1996). Factors such as class size, school size, teacher qualification (Ferguson, 1991), teacher preparation and certification (Darling-Hammond, 1999) and other school variables were found to determine what students learn.

In the past two decades, teachers' knowledge of mathematics has become an object of concern. New theoretical and empirical insights into the work of teaching (Shulman, 1986, 1987) have spurred greater attention to the role played by such knowledge in teacher education and the quality of teaching itself. No wonder, "mathematicians can be pleased to have at last powerful evidence that mathematical knowledge of teachers does play a vital role in mathematics learning" (Howe, 1999,

p.882). Howe argued that "a teacher who is blind to the coherence of mathematics cannot help students see it" (p.885). As Evan (1989) also puts it, "a teacher who has a solid mathematics knowledge . . . is more capable of helping his /her students achieve meaningful learning" (p.4). Furthermore, Shulman and Quinlan (as cited in Wilmot, 2008) indicated that, "Excellent teachers transform their own content knowledge into pedagogical representation that connect with their prior knowledge and dispositions of the learner" (p.35).

Quite recently, in response to the call for quality education in Ghana, greater attention has been given to the role that teacher characteristics play in students' achievement. To affirm this, the Director General of the Ghana Education Service, Mr. Samuel Bannerman Mensah, who served from 2007 to 2010, admitted that the success of the new education reforms depends largely on the tenacity of teachers (Daily Graphic, Monday, Aug. 10, 2009). He said teachers should be in the position to spark dramatic change in children at all times and interact with them to identify and solve the problem that might come their way. Concerns that teachers possess necessary knowledge and skills for teaching, have led to the development and use of external examination conducted by the Institute of Education, University of Cape Coast, primarily for certification purposes or graduation from teacher education programmes. Furthermore, in Ghana, prospective teacher trainees are required, in addition to their secondary school certificate, to pass an entry test or interview depending on the college that he/she is seeking to be admitted into. The above points to the fact that the teachers' need a certain level of academic ability in order to influence students learning.

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In order to help all Ghanaian young person's to acquire the needed mathematical skills, insight, attitude and values that they will need to be successful in their chosen careers and daily lives, the new mathematics syllabus in Ghana is based on the premises that all students can learn mathematics and that all need to learn mathematics (Ministry of Education, Core Mathematics Teaching Syllabus for Senior High School, 2007, p ii). Core mathematics is a compulsory subject for all Senior High School students in Ghana. All students are expected to pass this subject in the West African Senior Secondary Certificate Examination (WASSCE) at the end of their programme since it is one of the basic requirements for entry into Universities and other tertiary institutions in Ghana and many African countries. In spite of the compulsory nature of the subject, underachievement of students in mathematics at the Senior High School level continues to be mentioned in West African Examination Council Chief Examiners Reports (WAEC Chief Examiners' Report of 1998, 1999, 2000, 2001, 2003, & 2007). In particular, the Chief Examiner's reports of 1998, 1999, 2000, 2002 & 2004 indicated that students find it difficult to manipulate algebraic expressions and solve algebraic problems. If all students can and must learn mathematics and the teacher is an agent of change in the learning process, then the teaching knowledge of the teacher needs to be critically looked at.

This study therefore seeks a topic in the mathematics syllabus that is considered important to students' achievement and with which students are known to have difficulties. Algebra appears to be the foundational topic in the entire mathematics teaching syllabus at the Senior High School level in Ghana, hence the focus of the study on algebra.

The Purpose of the Study

The purpose of this study was to find out how teachers' knowledge for teaching correlates with their students' achievement in algebra at the Senior High School level in selected Senior high Schools in the Central Region of Ghana.

Research Hypothesis

"There is no significant relationship between teachers' knowledge for teaching algebra and their Senior High School students' achievement in algebra".

Methodology

Essentially, this study sought to find out whether students' achievement in algebra is affected by their teachers' knowledge for teaching. Since the aim was to find out possible relationship between the two variables without manipulating them, a correlation design was employed. This is so because a correlational design attempts to determine whether two or more variables are related and more so determine the strength of the relationship. It does so by the use of correlation and regression coefficients.

Sample and Sampling Technique

The target population for this study comprised all third year Senior High School students offering Elective Mathematics and their teachers in the Central Region of Ghana.

The accessible population from which the sample was drawn for this study was therefore all third year Elective Mathematics students in 10 selected Senior High Schools in the Central Region of Ghana. The 10 schools comprised four categories of schools; Category A, B, C and D according to the Ghana Education Service, (2009) classification. At the time of the study, there were seven Senior High Schools each in Category A and B, as many as twenty-two Senior High Schools in Category C and eleven schools in Category D. It came to light after the review that a similar study which was conducted by Wilmot (2008) made use of four of the seven Senior High

Schools in Category A. Using the three schools left in Category A as the basis, three schools were selected at random from each category using computer generated random numbers making a total of 12 schools at the start. However, two schools, one from Category A and D could not participate in the actual study. Two intact-Elective Mathematics classes were selected from each of the ten selected schools for the study making a total of 24 classes and 24 Elective Mathematics teachers for the study. Table 1 gives the breakdown of participants in each school category for the study.

Table 1: Participants by School Categories

	Category				
	A	**B**	**C**	**D**	**Total**
No of schools	2*	3	3	2*	10
No of Classes	4**	4**	6	4	18
No of Teachers	4	4	6	3***	17
No of Students	145	133	178	161	617

*Some schools could not take part in the study
**Some classes were combined into one class before the test was taken
***Some teachers could not take part in the study.

In a nut shell, the total sample for the study consisted of 10 Senior High Schools, 17 classes, 617 form three Senior High students offering Elective Mathematics and 17 Elective Mathematics teachers. The distribution of students by classes and school category are presented in Table 2.

Table 2: Distribution of Participating Students by Class and School Category

Categories	Class code	Number of students	Subtotal
A	A1	41	145
	A2	35	
	A3	33	
	A4	36	
B	B1	35	133
	B2	29	
	B3	36	
	B5	33	
C	C1	23	178
	C2	27	
	C3	30	
	C4	35	
	C5	32	
	C6	31	
D	D1	26	161
	D2	31	
	D3	35	
	D4	33	
	D5	38	
Total		617	617

Data Collection Procedure

A preliminary study was conducted after initial visits to the selected schools. Two schools each from Category A and Category D were chosen for the preliminary studies. This was done to ascertain the level of resources in the various categories of schools to justify the basis for selecting samples from each category of school. Upon visits to these schools, it was confirmed that indeed Senior High Schools in Category A were well resourced than Senior High Schools in Category D. For example, the two schools in Category A had additional classroom blocks with old blocks refurbished, enough furniture and computer laboratory. The two schools in Category D on the other hand lacked these facilities at the time of the study. A case in point is that teachers in one of the schools in Category D had no staff common room and had to work under trees.

With the help of two research assistants the instruments were administered to both students and teachers under close supervision and the responses retrieved on the same day. In each school, while students were responding to the items in their respective classrooms the teachers were taking theirs in the staff common room at the same time. However not all schools took the test on the same day. Each test was completed in not more than 60 minutes.

The two classes selected within a particular school had the test administered to them at the same time but in separate rooms except for a few schools where the two classes were taught by one teacher and had to be combined in one class to take the test. In all, each of the 17 teachers in the study took the algebra test. At most two teachers, one for each class, took the test in each school.

Data Analysis

Essentially, the hypothesis that was formulated requires the test for relationship between students' achievement and their teachers' knowledge on the teaching knowledge items. As such, the scores of students and that of their teachers on the achievement test were the data used to test this hypothesis. The teachers scores (independent variable) on the test were correlated with the students' class mean scores (dependent variable). Since the focus of the hypothesis was to compare students' scores with their own teachers' scores, students whose class teachers did not take part in the study were dropped from the analysis. The hypothesis requires the calculation of Pearson correlation coefficient and subsequently test for its significance. The Pearson correlation coefficient was appropriate because it is designed for such interval or continuous variables. The summary statistics of students' scores and the total scores of their teachers who participated in the study is presented in Table 3.

Table 3: Summary of Students Scores and their Teachers Total Scores

Class ID	Class size(N)	Class Mean Score	Std. Deviation	Teachers score
A1	41	6.05	1.746	13.00
A2	35	5.57	1.754	14.00
A3	33	4.39	1.903	5.00
A4	36	3.72	.974	8.00
B1	35	4.11	1.491	9.00
B2	29	4.48	1.864	7.00
B3	36	4.50	1.108	12.00
B4	33	5.12	1.431	16.00
C1	23	3.39	1.406	9.00
C2	27	3.52	1.282	7.00
C3	30	3.90	1.423	8.00
C4	35	4.69	2.180	11.00
C5	32	3.78	1.237	7.00
C6	31	3.00	1.095	8.00
D1	26	2.50	1.175	11.00
D2	31	3.90	1.350	7.00
D3	33	3.67	1.137	8.00

It can be observed from the Table 3 that the highest students' classes mean score was from a Category 'A' school whereas the least score was from a Category 'D' school. This was not surprising because schools in Category 'A' were well resourced than their counterparts in Category D at the time of the study. Again, a glance at the table also revealed that Category 'B' had the highest teachers' total score with Category 'A' recording the least teachers' total score. This is also not surprising because teachers are posted to the Senior High Schools regardless of their content and pedagogical knowledge.

A Preliminary analysis was conducted to investigate the relationship between the students' class mean scores and their teachers' total scores using a scatter plot. This preliminary analysis provided the basis for the choice of the Pearson correlation coefficient. The scatter plot of the teachers' total score and their students' class mean scores is displayed in Figure 1.
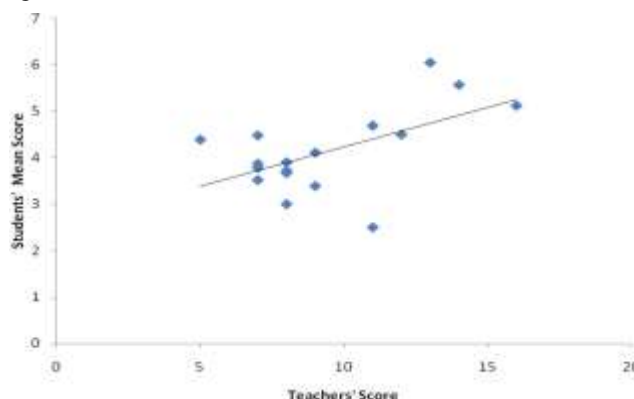

Figure 1: **Teachers' Knowledge and Students Achievement**

It can be seen from the scatter plot that there is a moderate linear relationship between the teachers' score and the students' mean score. The line of best-fit was thus laid as shown in Figure 1. The line also shows an upward trend, suggesting a positive linear relationship between the two variables.

The relationship between the teachers' knowledge and students' achievement was then investigated by calculating the Pearson moment correlation coefficient. Analysis shows that each variable was normally distributed as one of the inherent assumptions that must be met before using Pearson product-moment correlation coefficient. There was a moderate ($r = .557$, $N = 17$, $p < .05$) positive correlation between the teachers total scores and their students' class mean scores on the achievement test.

Since the correlation coefficient is an estimate of the population correlation coefficient, its value may be purely by chance even when there is no actual relationship between the two variables. As a result, a test was conducted using the t-test statistic to find out whether there is zero correlation in the population from which the sample was drawn. From the test, it was concluded that the correlation in the population could not be zero since the t-calculated value (2.55) was greater than the t-table value (2.13). It therefore suggests that high teachers' score tend to be associated with high students' score whereas low teachers' score tend to be associated with low students' score on the test achievement test conducted. The moderate correlation coefficient therefore suggests that there exist a linear relationship of the form $y = a + bx + \varepsilon$ between the two variables under study.

To confirm or otherwise that the regression model was appropriate, a Lack-of-fit test was conducted. The reason for using the lack-of-fit test was due to the nature of the data collected for the study. The data was such that there were more than one observation per level of the independent variable. Thus, one teacher's score (independent variable) has more than one student's score (dependent variable) in his or her class.

For specified value of α, reject the null hypothesis (the adequacy of the model) if the computed value of F exceeds the table value. That is, if the F test is significant, it indicates that the linear regression model is inadequate. A non-significant result indicates that there is insufficient evidence to suggest that the linear regression model is inappropriate. Table 4 presents a basic output based on a simple linear regression of students'

scores and that of their teachers to examine the Lack-of-Fit. The following hypotheses were formulated and tested at the 0.05 level of significance.

H_o: A linear regression model is appropriate.

H_1: A linear regression model is not appropriate.

Table 4: Summary of Lack-of-Fit Test for the Regression Model

Source	d.f	SS	MS	F
Regression	1	317.993	317.993	
Lack of fit	529	93.433	0.176	0.0022
Pure Error	15	1190.574	79.372	
Total	545	1602.498		

From Table 4, it can be seen that the lack-of-fit-test was not significant at .05 level of significance as such H_0 could not be rejected. It was therefore concluded that there is insufficient evidence to suggest that the linear regression model is inappropriate. In other words, the linear regression model was adequate for the relationship between the teachers' total scores and their students' class means scores on the achievement test in algebra.

To determine the nature of the relationship, the regression analysis was then performed. The model to be tested was; $y = a + bx + \varepsilon$, where $y =$ the dependent variable (class mean score), $x =$ the independent variable (teachers' total score), $a =$ the class mean score when the independent variable (the intercept) is zero, $b =$ the change in the class means score for a unit change in teachers' score, $\varepsilon =$ the error term for the class mean score (the ε's are assumed to be independently and normally distributed with mean of 0 and variance, σ^2). Table 5 shows the coefficients in the regression model.

Table 5: Coefficients of Linear Regression Model

Variable	Unstandardized Coefficients			
	B	Std. Error	t	p-value
Constant	2.542	.639	3.980	.001
Teachers scores	.169	.065	2.605	.020

The coefficients in the model are the values in the output column B. The linear model was estimated as

$$E(y) = 2.542 + .169x,$$ where y is the dependent variable representing the class mean score and the x independent variable representing the teachers' total score.

The linear regression model connecting the teachers' total score and the students mean score was then interpreted as follows:

First, the equation indicates that for a unit change in the predictor variable, x, the dependent variable y changes by 0.169. Furthermore, the equation shows that when the independent variable x, is zero, the expected value of y is 2.542. In this case x (teachers' score) is not important in the equation. To investigate whether the independent variable was important or significant in the model, the following hypothesis was tested at 0.05 level of significance.

$H_0: b = 0$ (x is not significant) against

$H_1: b \neq 0$ (x is significant)

The test statistic to ascertain the significance of the regression coefficient was calculated using the t-test statistic. In this test, H_0 is rejected if the t-value calculated is greater than t-value from table. In that case $b \neq 0$ and that the value of y

(students' score) depends on the value of x (teachers' score). The linear model is thus useful for prediction. Otherwise x is not significant and the model cannot be used for prediction. At $\alpha = 0.05$ significance level, the test was significant since $p < 0.02$ (see Table 7). We therefore reject H_0, and conclude that the coefficient b cannot assume the value 0.

The coefficient of determination, which indicates how much of the variability in the dependent variable is explained by the model, was computed by squaring the correlation coefficient (r = 0.588). The R-squared value of 0.31 shows that about 31% of the variation in the class means score is explained by the model. Although this value is moderate, Cohen (1988) considered it large. It was therefore concluded that there is a statistically significant positive linear relationship between students score and teachers' total score on the achievement test.

Results and Discussion

It was hypothesized that the relationship between students' achievement and their teachers' knowledge may exist below a certain minimum bound of knowledge (Begle, 1972). Based on this, the study used samples across four school categories, ranging from well-resourced to least resourced schools (GES, 2009). The correlation coefficient of 0.557 indicates that a moderate linear relationship existed between the Elective Mathematics students' achievement and their teachers' teaching knowledge in algebra. The positive correlation implies that there is a direct variation between the two variables. Thus, high values in the teachers score tend to be associated with high values in their students achievement while low values in the teachers score tend to be associated with low values in their students' achievement. It was evident from the lack-of-fit test that a linear regression model between the teachers' score and their students' score was appropriate. A simple linear regression was then fitted to investigate how well teachers' scores predict students' achievement scores. The result was statistically significant, $F(15) = 6.738$, $p < 0.005$. The identified equation to understand this relationship was:

Students achievement score (y) = 2.542 + 0.169 teacher's total score (x).

The adjusted R squared value was 0.31. This indicates that 31% of the variation in students achievement is explained by the teachers output. Although this looks moderate, Cohen (1988) considers such values as having a large effect. This means that there is a linear relationship between the teacher's knowledge for teaching and their students' achievement in mathematics.

The following conclusions could be drawn from the model: It was concluded that a positive linear relationship existed between the achievement of Senior High School students who participated in the study and their teachers on the achievement test conducted. The positive coefficient of x, teachers' total score implies that, teachers' knowledge has positive effect on students' achievement. This means that for every unit change (increase) in teachers' total scores on the achievement test conducted, the mean scores of their students' will increase by 0.169 as far as this study is concerned. The significance of the change when tested was statistically significant in the model. Furthermore, the positive constant term (2.542) in the model implies that after controlling for teachers scores, the class mean scores of the students would remain positive. This is because other factors which were not considered in this study could also have a positive effect on students' achievement in mathematics. This may explain the low R-square value obtained. Caution

should therefore be taken in using the model for predicting future scores of students.

Perhaps the significant positive linear relationship between teachers' teaching knowledge and students' achievement in this study is a confirmation of Begle's (1972) concluding remarks that there is a minimum threshold of teacher knowledge below which the relationship between teachers knowledge and students achievement exists. Begle explained that the non-significant relationship between teachers' knowledge and students' achievement in algebra was as a result of the fact that all the teachers who participated in his study came from well-motivated and well-resourced schools. Furthermore, the result was synonymous to Darling-Hammond (2000) who contended that initially, the relationship between content knowledge and students' achievement appears to be a positive linear one but this becomes stable after some time. However, Monk (1994), and Rowan, et.al, (2002), contended that teachers' content knowledge produces virtually no returns in terms of the impact on the achievement of their students. It was evident from their studies that the relationship becomes meaningless as the teacher's number of advance mathematics courses increases, more so beyond five courses

In relation to the hypothesis, there was a significant positive linear relationship between the teaching knowledge of teachers who participated in the study and the achievement of the students of their classes. It was concluded that, for those who participated in this study, teachers' teaching knowledge contribute to their students' achievement in mathematics. The linear model connecting the two variables reveals that an increase in teacher knowledge would invariably cause an increase in student achievement. This means that in a class, if the teacher's knowledge for teaching algebra is relatively high his or her students are likely to have high mathematics achievement scores.

The model which was established to explain the relationship between the two variables was: $y = 2 \cdot 542 + 0 \cdot 169x$. The positive coefficient of x in the regression model means that, holding all other confounding factors constant, a unit increase in the total score of the participating teachers would cause an increase of 0.169 in the class mean scores of the students of their classes. The analysis of variance test which was conducted to test the significance of the predictor variable reveals that about 31% of the variation in the class means score is accounted for by the model. It was therefore concluded that, for schools that participated in the study, the teachers' knowledge significantly affect students' achievement in mathematics. As required of the instrument for this study, most of the participating students indicated that they pay their mathematics teachers to provide them extra tuition for at least 2 hours a week. This might have greatly improved the performance of the students in mathematics, hence the positive coefficient of x. This finding is in consonance with other studies which generally indicated that teachers' knowledge does help in predicting their students' achievement (Hill, Rowan & Ball, 2005; Mullens et al., 1996; Sanders and Rivers, 1996). Perhaps that explains why researchers have directed their attention on looking more closely at the substance of teachers' knowledge, particularly knowledge assumed necessary for teaching in Africa and other parts of the world.

Finally, the positive constant term in the model means that holding the effect of teachers' knowledge, the class mean score of students of the participating school would remain positive. Again students who participated in the study indicated that quite apart from the extra tuitions their teachers provide for them, they have extra learning resources from home. This implies that students equally learn a great deal of mathematics independent of their teachers which could account for the high positive constant term in the model.

Conclusion

There was a significant positive linear relationship between the teaching knowledge of teachers who participated in the study and the achievement of the students of their classes. It was concluded that, for those who participated in this study, teachers' teaching knowledge contribute to their students' achievement in mathematics. The linear model connecting the two variables reveals that an increase in teacher knowledge would invariably cause an increase in student achievement. This means that in a class, if the teacher's knowledge for teaching algebra is relatively high his or her students are likely to have high mathematics achievement scores. The model which was established to explain the relationship between the two variables was: $y = 2 \cdot 542 + 0 \cdot 169x$

Recommendations

First, the study revealed that mathematics teachers' knowledge has a direct relationship with the achievement of students' of their own classes. This study used only ten public Senior High Schools in the Central Region of Ghana. It is therefore recommended that a similar study is conducted to include Senior High Schools from all the ten regions of Ghana. Such studies would provide additional information for refinement and improvement in students' performance. A similar study which includes Senior High Schools in all the ten regions would be helpful in drawing a more generalize conclusion on this subject.

Second, research should be conducted to investigate additional factors that may possibly be related to students' achievement in mathematics since the analysis revealed that about 31% of the variation in the teachers score accounted for students' achievement in algebra. The remaining 69% could be other factors that may possibly affect students learning and needs to be research into.

Third, an in-depth study of teachers teaching knowledge that provides videotapes rather than snapshots of teachers' knowledge should be conducted. This is because the current study relied on the scores of students on an achievement test conducted at a sitting. A study which includes, observations and interviews on what and how mathematics teachers teach algebra in the classroom could provide additional information on the relationship between teachers' knowledge and students' achievement in mathematics.

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