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MEASUREMENT OF TEACHER KNOWLEDGE: UNEARTHING HIDDEN DIFFERENCES AMONG DIFFERENT CATEGORIES OF MATHEMATICS TEACHERS IN GHANA

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ABSTRACT: *Literature on teacher competence and student performance is replete with arguments that graduates of teacher education programmes feel better prepared for their job and can positively affect their students' achievement than those who enter teaching without adequate teacher education background. These issues of pedagogical preparation, subject matter preparation and experience are especially important in the case of Ghana due to the different categories of mathematics teachers at the senior high school level. Using the causal comparative research design, this study investigated the differences in the knowledge for teaching algebra among different categories of senior high school mathematics teachers in Ghana. In all, 38 in-service and 301 prospective senior high school mathematics teachers; comprising 132, 44, and 125 respective final year university students majoring in mathematics, statistics and mathematics education participated in the study. Analysis of data from this study revealed that in-service high school teachers in Ghana performed significantly better than each sub-group of the prospective mathematics teachers who participated in the study. Recommendations have been made on the need to provide more real classroom experiences that have the potential of helping prospective teachers to improve their content and pedagogical content knowledge.*

KEY WORDS: Mathematics teacher knowledge, Measurement of knowledge for teaching high school algebra, Differences in teacher knowledge, Value added by teacher education

INTRODUCTION AND BACKGROUND

Literature on teacher competence and student performance is replete with studies that project the value added by teacher education. These studies show that graduates of teacher education programs feel better prepared for their job and can positively affect their students' achievement than those who enter teaching without adequate teacher education background (see Kennedy, 1991; Darling-Hammond, 2003; Laczko-Kerr & Berliner, 2003; Kennedy, Ahn & Choi, 2006). These issues of pedagogical preparation, subject matter preparation and experience are especially important in the case of Ghana due to the manner in which teachers are recruited for the senior high school level. For instance, in Ghana university graduates in mathematics education, as well as those majoring in mathematics or a relating area could be posted to teach mathematics at the senior high school for their one-year national service. After their national service, many of these remain as teachers in the schools. Though some of those without education background return to the University of Cape Coast or the University of Education, Winneba for the professional training in education, a few remain until they retire from active service. This brings to the fore the question as to what the knowledge base of the different categories of senior high school mathematics teachers in Ghana fall on to help them promote powerful and flexible knowledge and understanding in students.

The paper agrees that this question of measuring the knowledge base of teachers has not been easy to answer in part due to the different conceptualizations so far given of teachers' knowledge (see for example, Thompson, 1984; Leinhardt & Smith, 1985; Shulman, 1986; Cochran & Jones, 1998;Ma, 1999; Ball & Bass, 2000; Hill, Ball & Schilling, 2004; Hill, Rowan & Ball, 2005). For instance, Thompson (1984) argued that the type of mathematical knowledge teachers draw upon in teaching could be influenced by their beliefs, views and preferences about the subject. Leinhardt and Smith (1985) proposed two types of teacher knowledge; *lesson structure knowledge* (LSK) and *subject matter knowledge* (SMK). When Shulman and his colleagues came into the scene (Shulman, 1986) they also introduced, among other things, the idea of *pedagogical content knowledge* (pck), while Ma (1999) brought up the idea of *profound understanding of fundamental mathematics* (PFUM).

The problem with several of these conceptualizations is that they are too generalized, not domain-specific, and therefore not lend themselves to direct measurements. Consequently, in the past, several proxy measures have been used to measure mathematics teacher knowledge. In Ghana and many African countries, for instance, all that is needed to teach mathematics at the high school level is a university degree in mathematics education, mathematics or a related discipline (see for example, Hanushek 1972; Boardman, Davis & Sanday, 1977; Strauss & Sawyer, 1986; Ferguson 1991; Harbison & Hanushek, 1992; Tatto, Neilsen, Cummings, Kularatna & Dharmadasa, 1993; Mullens, Murnane & Willett, 1996; Rowan, Chiang, & Miller, 1997).

In other countries, in addition to a prior university coursework in mathematics or a related discipline, performance on certification examinations or other forms of examinations have traditionally been used as a measure of teacher knowledge. In the US, for instance, to be certified to teach mathematics, various states require pre-service teachers to pass a mathematics test. An example of this is PRAXIS, a teachers' licensing examination developed by Educational Testing Service (ETS), which is currently used by over 30 states. Such efforts are meant to ensure that mathematics teachers have a good knowledge of the mathematics students are required to learn in school.

In spite of this, the quality of achievement of K-12 students in mathematics has continued to be of national concern in the US. For example, when the U.S. Department of Education in the late 1990s identified that a clear need existed for improvement in mathematics proficiency in U.S. schools, the RAND Mathematics Study Panel chaired by Deborah Loewenberg Ball was convened between 1999 and 2003, to inform the U.S. Department of Education's Office of Educational Research and Improvement on ways to improve the quality and usability of education research and development. The panel identified three areas for focused research and development (see Ball, 2003). These included the need for further clarification of the knowledge demands of teaching mathematics, and a deeper understanding of ways to provide opportunities for prospective and practicing teachers to acquire this kind of knowledge. In addition, the RAND

Mathematics Study Panel recommended the development of instruments for assessing the mathematical knowledge for teaching across grade levels and mathematical domains. The RAND panel also singled out algebra as an important area of focus in all these efforts.

At the senior high school level, and in line with RAND panel recommendations, Ferrini-Mundy and her colleagues on the Knowledge of Algebra for Teaching (KAT) project have conceptualized and framed questions about mathematical knowledge for teaching algebra (see for instance, Ferrini-Mundy, Burrill, Floden, & Sandow, 2003; Ferrini-Mundy, Senk, & McCrory, 2005). In their conceptualization, The KAT project has hypothesized that mathematical knowledge for teaching algebra consists of three types of knowledge. These are, 1) knowledge of school algebra (referred to later in this paper as "school knowledge" as used by the KAT project team), 2) advanced knowledge (i.e., knowledge of the content of other mathematics domains different from algebra) and 3) teaching knowledge. Based on this conceptualization, members of the KAT project have developed items and designed instruments to measure knowledge for teaching algebra at the senior high school level.

The importance of the KAT work can be seen in the fact that, after two decades of various conceptualizations of the knowledge base for teaching, the KAT project was a specific attempt at focusing on conceptualizing the knowledge required for teaching in one specific domain of mathematics at the senior high school level (i.e., algebra). Another thing that made the KAT project unique is the work it has done towards developing tools for assessing mathematical knowledge for teaching algebra. The KAT conceptualization had the potential of becoming a good framework for other researchers who may be interested in conceptualizing knowledge demands for teaching other domains of mathematics especially at the senior high school level. In addition, the KAT instrument could serve as a potential tool for accessing and improving knowledge of pre-service teachers or for professional development of in-service high school algebra teachers.

In the light of the foregoing, this study adopted the KAT project instruments to examine issues of knowledge for teaching algebra among prospective and in-service senior high school mathematics teachers in Ghana. Precisely, the study sought to investigate how the profile of knowledge for teaching algebra, based on the KAT project conceptualization differed among the different categories of prospective and in-service senior high school mathematics teachers in Ghana.

RESEARCH DESIGN

This study adopted the Causal comparative or Ex-post-facto design. This is the type of research in which researchers to investigative the cause or consequences of differences that already exist between or among groups of individuals (i.e., it is a form of association research). In this study, four different populations were identified. These were: 1) pre-service mathematics education students in the final year of their college preparation program, 2) final year mathematics major students (considered possible prospective teachers), 3) final year statistics major students (also considered possible prospective teachers) and 4) in-service teachers from the participating senior senior high schools. Ex-post-facto design was used because the profile of knowledge for teaching algebra among the four categories of participants existed prior to the study and no steps were taken to alter them in the study.

INSTRUMENTATION

As already discussed, the study involved administering mathematics assessment instruments adapted from the Knowledge of Algebra for Teaching (KAT) project at Michigan State University (MSU) to participants of the study. The adaptations involved changing the contexts and wording of questions in the KAT instrument to reflect Ghanaian contexts. For Instance, the US currency in some of the questions was changed into the Ghana Cedis, the Ghanaian currency, and the prices of the items were also changed to reflect market values in Ghana at the time of the study. In addition, variations in names of words used were also changed to reflect the right contexts in Ghana. For example, a word such as, "pants" was changed into "trousers" as is commonly called in Ghana.

The KAT project had developed two instruments each composed of twenty items; seventeen multiple-choice and three open-ended content items. The items were based on the three hypothesized types of knowledge the algebra in the senior secondary school syllabus (i.e., school knowledge items), content outside of high school algebra (i.e., advanced knowledge), and on the tasks of teaching (i.e., teaching knowledge items). In an earlier study the scores of participants completing the two were found not to be significantly different (see Wilmot, 2008).The instruments used for the study could not be displayed in the appendix because the KAT project that owns the copyright has at the time of the writing of this study had not made them public.

PROCEDURE

Initial discussions were held with the heads of departments at two public universities where degree programmes in mathematics education, mathematics and statistics are offered in Ghana the heads senior high schools in Accra, Kumasi, Cape Coast and Takoradi. In all, teachers from eight of the senior high schools visited agreed to participate. As already discussed, this study involved administering the instrument adapted from the KAT project to participants of the study.

At the senior high schools meetings were also held with the mathematics teachers and those who agreed to participate were used for the study. Similarly, at the universities meetings with the final year mathematics education, mathematics and statistics were also organized and only students who agreed to participate were allowed to do so in the study. During these discussions, the purpose and steps to be taken in the study were discussed. In addition, verbal approval was obtained to use the institutions as sites for the study.

Administration of the instruments commenced from the senior high schools. In each school the in-service teachers who agreed to participate were brought together to complete the instruments at a sitting lasting no more than 60 minutes. Administration of the instruments in the universities was done in a slightly different manner. The universities were writing their end-of-semester examinations at the time of the visit. However, opportunity was provided for students who agreed to participate to come together to complete the instruments on the common days that they had no papers to write. This made it possible for participants in each department of the three universities to complete the instrument at a sitting lasting no more than 60 minutes. Participants were made to complete the instrument in spaces provided in the instrument to ensure that the questions did not leak to participants who completed them later than their colleagues in the different institutions and departments.

ANALYSIS OF DATA

As already mentioned the purpose of the study was to investigate using, the KAT project categorization, how the profile of knowledge for teaching algebra differed among the different categories of senior high school mathematics teachers and potential teachers in Ghana.
Data for this research question came from the in-service teachers and university students. To answer this question, analysis of variance (ANOVA) was performed on the scores of the various categories of participants for participants on the various hypothesized types of knowledge and the total scores on the instrument. This was be useful in establishing how the three types of knowledge (school knowledge, advanced knowledge and teaching knowledge) differed among the different categories of potential senior high school teachers and the in-service senior high school mathematics teachers in Ghana.

Table 1: Descriptive statistics of scores from participants

					95% Confidence Interval for Mean			
Major	N	Mean	Std. Dev.	Std. Error	Lower Bound	Upper Bound	Min	Max
Math	132	9.140	2.711	.236	8.670	9.607	3.00	17.50
Math Ed	125	7.676	2.030	.181	7.317	8.035	2.50	12.50
Statistics	44	7.977	2.277	.343	7.284	8.670	.50	11.00
In-service	38	13.184	2.822	.458	12.257	14.112	7.50	19.50
Total	339	8.903	2.940	.160	8.589	9.217	.50	19.50

A cursory look at Table 1 reveals that the mean scores were different for each of these four groups of teachers. As shown in Table 1 above, in this study, the group that performed best on the total score of the combined forms was the in-service teachers. On the other hand, the group that scored least was the mathematics education majors. These relative mean scores of participants majoring in the different domains is presented graphically in Figure 1 below.

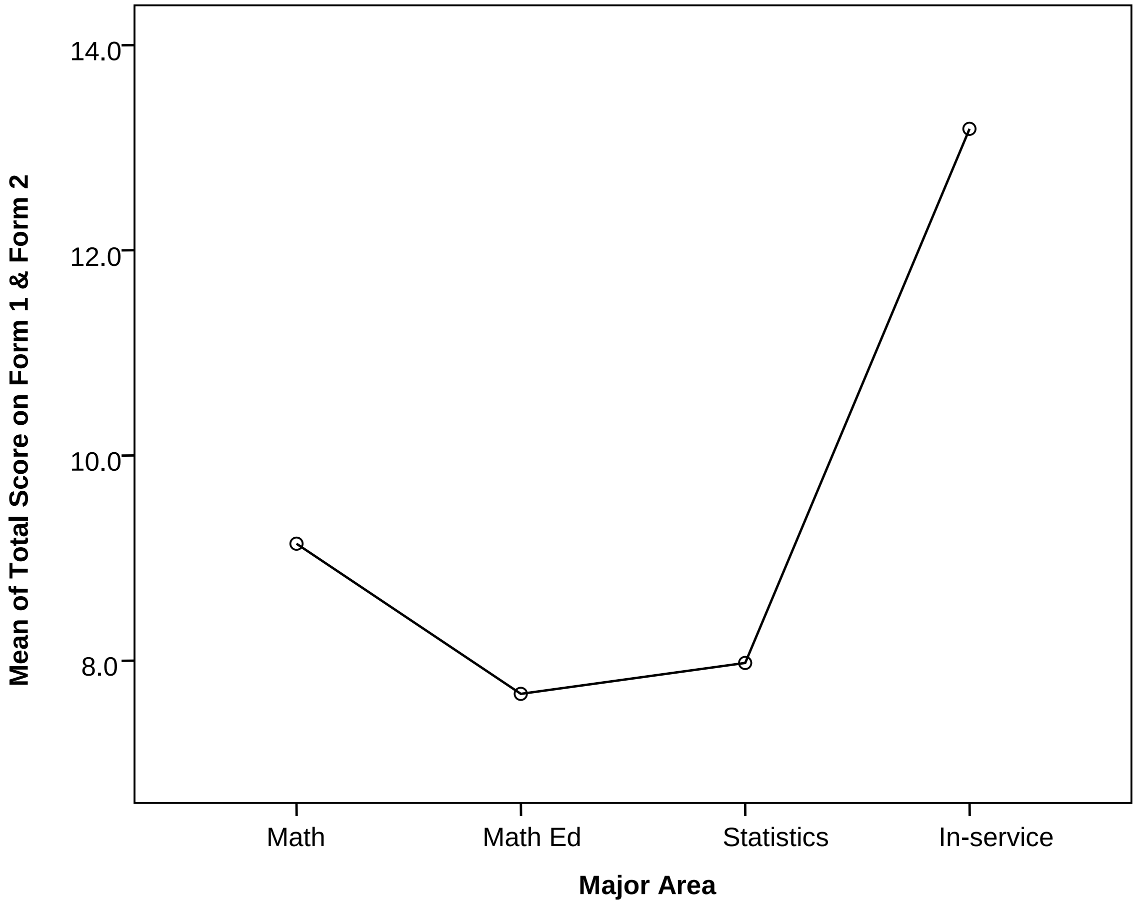

Figure 1: Distribution of mean total score on the combined form for all groups

Levene's test was used to test the assumption of homogeneity of variances. The Table 2 below presents the results of the Levene's homogeneity test.

Table 2: Test of Homogeneity of Variances among the Four Groups

Levene Statistic	df1	df2	Sig.
3.343	3	335	.019

From the outcome of the homogeneity test, it was observed that the value under Sig. is less than .05. Thus, the group variances are significantly different. This means that the group variances are not approximately equal. This was not surprising since in one-way ANOVA the unequal sample sizes can affect the homogeneity of variance assumption. However, ANOVA is considered robust to moderate departures from the assumption of homogeneity of variances. And since there isn't a good rule of thumb for the point at which unequal sample sizes make heterogeneity of variance a problem, a decision was made throughout the analyses to go-ahead and use ANOVA to examine whether the group means of the four groups were significantly different or not. The results of this test for the total scores are presented in Table 3 below.

Table 3: ANOVA table for Mean Differences in Total Scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	929.815	3	309.938	52.150	.000
Within Groups	1990.973	335	5.943		
Total	2920.788	338			

Table 3 above shows that there is a large F-ratio (i.e., 52.150) for the Between-Groups variance. In addition, there is an associated F probability (.000), smaller than the 0.05 significance level. Thus, there seems to be adequate evidence that there is a difference overall for at least one pair of these four groups. To investigate which particular pairs of groups have significant between mean differences, Tukey's Honestly Significant Difference (HSD) Tests was used at the 5% level of significance. Tukey's HSD Test is useful because it presents results of multiple comparisons among all the possible pairings of the groups of focus, in this case, of the four groups of mathematics, mathematics education and statistics majors, as well as in-service high school mathematics teachers in Ghana. The result of this multiple comparisons is presented in Table 4.

Table 4: Multiple Comparisons of Differences in Total Scores

(I) Major Area	(J) Major Area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Upper Bound	Lower Bound
Math	Math Ed	1.464*	.304	.000	.679	2.250
	Statistics	1.163*	.424	.033	.067	2.259
	In-service	-4.044*	.449	.000	-5.202	-2.885
Math Ed	Math	-1.464*	.304	.000	-2.250	-.679
	Statistics	-.301	.427	.895	-1.405	.802
	In-service	-5.508*	.452	.000	-6.674	-4.342
Statistics	Math	-1.163*	.424	.033	-2.259	-.067
	Math Ed	.301	.427	.895	-.802	1.405
	In-service	-5.207*	.540	.000	-6.601	-3.813
In-service	Math	4.044*	.449	.000	2.885	5.203
	Math Ed	5.508*	.452	.000	4.342	6.674
	Statistics	5.207*	.540	.000	3.813	6.601

* The mean difference is significant at the .05 level.

Table 4 shows that at the 5% level of significance, the in-service teachers had significantly higher score than any group of university students. In addition, the mathematics students had a significantly higher score than the statistics and mathematics education students. The only groups that did not perform significantly different from each other were the statistics and mathematics education students.

With these differences observed among the four groups, it was necessary to test for whether the groups will show similar differences in the scores of the subtotal of school knowledge, advanced knowledge and teaching knowledge. The next three subsections presents results of such analyses.

In the next three sections the same procedure followed in the current section was used in presenting the results of ANOVA performed subtotal scores on items that measured the three knowledge types hypothesized in this study. The descriptive statistics of the subtotal score for each knowledge construct will first be presented and discussed before the subsequent results (e.g. Levene's homogeneity of variance test, ANOVA test of possible significant differences and Tukey's test) that culminate in helping to examine differences in group means are presented in turn.

Analysis of Variance (ANOVA) on School Knowledge

Table 5 shows the descriptive statistics obtained from the data analysis of scores from the school knowledge items.

Table 5: Descriptive Statistics of School Knowledge scores

					95% Confidence Interval for Mean			
Major	N	Mean	Std. Dev.	Std. Error	Lower Bound	Upper Bound	Min	Max
Math	132	3.576	1.205	.105	3.368	3.783	1.00	6.00
Math Ed	125	3.024	1.000	.089	2.847	3.201	1.00	5.50
Statistics	44	3.716	1.014	.153	3.408	4.024	.50	6.00
In-service	38	4.460	1.159	.188	4.080	4.841	2.50	6.50
Total	339	3.490	1.184	.064	3.363	3.616	.50	6.50

A cursory look at Table 5 reveals that the mean school knowledge scores were different for each of these four groups of teachers. As shown in Table 5 above, in this study the group that performed best on the school knowledge items was the in-service teachers. On the other hand, the group that scored least on the school knowledge items was the mathematics education majors.

To examine whether the group mean scores on the school knowledge items are significantly different or not, the ANOVA table was used. The results of this test are presented in Table 6.

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Table 6 ANOVA table for Mean Differences in School Knowledge

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	66.154	3	22.051	18.103	.000
Within Groups	408.060	335	1.218		
Total	474.214	338			

Table 4.2.10 below shows that there is a large F-ratio (i.e., 8.103) for the Between-Groups variance. In addition, there is an associated F probability (.000), smaller than the 0.05 significance level. It was therefore concluded that there seems to be adequate evidence that there is a significant difference in the mean scores on the mean school knowledge items for at least one pair of these four groups.

To investigate which particular pairs of groups have significant between group mean differences, Tukey's HSD Tests was used at the 5% level of significance. Tukey's HSD Test is useful because it presents results of multiple comparisons among all the different pairings, in this case, of the four groups. The result of this multiple comparisons is presented in Table 4.2.11 below.

Table 7: Multiple Comparisons of Differences in School Knowledge

(I) Major Area	(J) Major Area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Upper Bound	Lower Bound
Math	Math Ed	.552*	.138	.000	.196	.907
	Statistics	-.140	.192	.885	-.636	.356
	In-service	-.885*	.203	.000	-1.409	-.360
Math Ed	Math	-.552*	.138	.000	-.907	-.196
	Statistics	-.692*	.193	.002	-1.191	-.192
	In-service	-1.437*	.204	.000	-1.964	-.909
Statistics	Math	.140	.192	.885	-.356	.636
	Math Ed	.692*	.193	.002	.192	1.191
	In-service	-.745*	.244	.013	-1.376	-.113
In-service	Math	.885*	.203	.000	.360	1.409
	Math Ed	1.437*	.204	.000	.909	1.964
	Statistics	.745*	.244	.013	.113	1.376

* The mean difference is significant at the .05 level.

Table 7 shows that at the 5% level of significance, the in-service teachers had significantly higher school knowledge than any group of university students. In addition, the statistics and mathematics majors respectively had higher school knowledge than the mathematics education majors (who had the lowest school knowledge). However, there was no significant difference between the level of school knowledge of the statistics and mathematic majors.

Analysis of Variance (ANOVA) on Advanced Knowledge

The table below, Table 8, presents the means and standard deviations of the level of advanced knowledge for each of the four sub-groups. The table reveals that in-service teachers had highest level of advanced knowledge, followed by mathematics majors, mathematics education majors and statistics majors in that order. Before the fieldwork, it was hypothesized that the mathematics majors would have higher level of advanced knowledge than the in-service teachers. However, data from this study show the converse. Table 8 below reveals this.

Table 8: Descriptive Statistics of Advanced Knowledge scores

					95% Confidence Interval for Mean			
Major	N	Mean	Std. Dev.	Std. Error	Lower Bound	Upper Bound	Min	Max
Math	132	2.087	1.262	.110	1.870	2.304	.00	5.50
Math Ed	125	1.652	1.018	.091	1.471	1.832	.00	4.00
Statistics	44	1.352	.944	.142	1.065	1.639	.00	3.00
In-service	38	3.329	1.420	.230	2.862	3.796	1.00	7.00
Total	339	1.970	1.278	.069	1.834	2.107	.00	7.00

These mean scores are presented graphically in Figure 3.

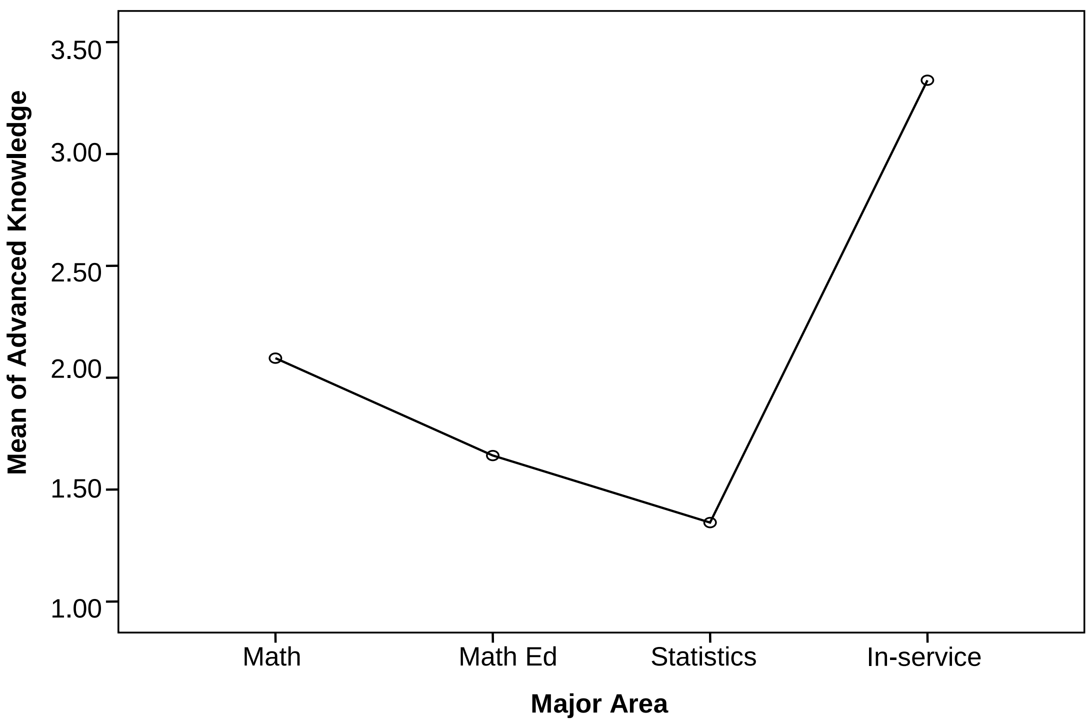

Figure 3: Distribution of mean advanced knowledge for all four subgroups

Table 9: ANOVA table for Mean Differences in Advanced Knowledge

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	101.417	3	33.806	25.150	.000
Within Groups	450.288	335	1.344		
Total	551.705	338			

From the large F-ratio (25.150) in the ANOVA table for the Between Groups variance and its associated F-probability (.000 <.05), it was concluded that there seems to be adequate evidence that some pairs of groups had differences in their mean scores that were significant. To examine which particular pairs of subgroups had such significant differences in their group means, Tukey's HSD Test of was used (see Table 10 for the multiple comparisons).

Table 10: Multiple Comparisons of Differences in Advanced Knowledge

(I) Major Area	(J) Major Area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Upper Bound	Lower Bound
Math	Math Ed	.435*	.145	.015	.061	.809
	Statistics	.735*	.202	.002	.214	1.256
	In-service	-1.242*	.213	.000	-1.792	-.691
Math Ed	Math	-.435*	.145	.015	-.809	-.061
	Statistics	.300	.203	.454	-.225	.824
	In-service	-1.677*	.215	.000	-2.231	-1.122
Statistics	Math	-.735*	.202	.002	-1.256	-.214
	Math Ed	-.300	.203	.454	-.824	.225
	In-service	-1.977*	.257	.000	-2.640	-1.314
In-service	Math	1.242*	.213	.000	.691	1.793
	Math Ed	1.677*	.214	.000	1.122	2.231
	Statistics	1.977*	.257	.000	1.314	2.640

* The mean difference is significant at the .05 level.

Table 10 shows that at 5% level of significance, the mean differences between the advanced knowledge of each pair of subgroups were significant except for the pair of statistics and mathematics education majors. In other words, at the 5% level, the in-service teachers had significantly higher advanced knowledge than any group of university students. In addition, the mathematics majors had significantly higher advanced knowledge (mean of 3.329) than the mathematics education majors (mean, 2.087) and the statistics majors. Unlike the school knowledge, mathematics education majors did not have the lowest level of advanced knowledge. Their mean score of 1.652 was higher than their statistics major counterparts who had 1.352 but this difference was not significant.

Analysis of Variance (ANOVA) on Teaching Knowledge

As was the case with the school knowledge and advanced knowledge items, in-service teachers in this study scored best on the teaching knowledge items. They had a mean score of 5.395 (refer to Table 11 below). The next highest mean scores were those obtained by the mathematics majors and statistics majors. They had mean scores of 3.477 and 2.909 respectively. The group that scored least on the teaching knowledge items was the mathematics education majors. They had a mean score of 2.909. The results are represented in Table 11 below.

Table 11: Descriptive Statistics of Teaching Knowledge scores

					95% Confidence Interval for Mean			
	N	Mean	Std. Dev.	Std. Error	Lower Bound	Upper Bound	Min	Max
Math	132	3.477	1.388	.121	3.238	3.716	1.00	7.00
Math Ed	125	3.000	1.220	.109	2.784	3.216	.50	6.50
Statistics	44	2.909	1.365	.206	2.494	3.324	.00	5.50
In-service	38	5.395	1.434	.233	4.923	5.866	2.00	7.50
Total	339	3.442	1.514	.082	3.280	3.604	.00	7.50

Next the ANOVA table was used to test whether differences in the group means were significant. Table 12 below presents these results. As would be observed from the ANOVA table, Table 12 below, there was a significant difference in the mean between certain pairs of the four subgroups (F-probability, .000 < .05).

Table 12: ANOVA table for Mean Differences in Teaching Knowledge

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	181.981	3	60.660	34.260	.000
Within Groups	593.147	335	1.771		
Total	775.128	338			

Next, Tukey's HSD Tests was used to test which particular pairs of subgroups had differences in their group means at the 5% level of significance. The results of this test are presented in Table 13 below.

Table 13: Multiple Comparisons of Differences in Teaching Knowledge

(I) Major Area	(J) Major Area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Upper Bound	Lower Bound
Math	Math Ed	.477*	.166	.022	.048	.906
	Statistics	.568	.232	.069	-.0230	1.166
	In-service	-1.917*	.245	.000	-2.550	-1.285
Math Ed	Math	-.477*	.166	.022	-.906	-.048
	Statistics	.091	.233	.980	-.511	.693
	In-service	-2.395*	.246	.000	-3.031	-1.758
Statistics	Math	-.568	.232	.069	-1.166	.030
	Math Ed	-.0909	.233	.980	-.693	.511
	In-service	-2.486*	.295	.000	-3.246	-1.725
In-service	Math	1.917*	.245	.000	1.285	2.550
	Math Ed	2.395*	.246	.000	1.758	3.031
	Statistics	2.486*	.295	.000	1.725	3.246

* The mean difference is significant at the .05 level.

From Table 13, it can be seen that the in-service teachers had a significantly higher teaching knowledge than each subgroup at the 5% level. Mathematics majors also had significantly higher teaching knowledge than the mean teaching knowledge of the mathematics education majors. However, there were no significant difference between the mean teaching knowledge of the mathematics majors and the statistics majors. In the same way, the difference in mean scores of the statistics majors and that of mathematics education on the teaching knowledge items was not found to be significant.

CONCLUSIONS FROM THE STUDY

Results of the analysis of variance (ANOVA) conducted in this study reveal that in Ghana, in-service high school teachers in Ghana performed significantly better than each sub-group of prospective mathematics teachers majoring in mathematics, mathematics education and statistics from the country’s universities. It was therefore concluded that knowledge for teaching algebra of in-service high school mathematics teachers is significantly different from that of prospective teachers (i.e., the three categories of university seniors majoring in mathematics, mathematics education and statistics).

This finding from the study is consistent with the argument by Sherin (2002) that in the course of teaching new curriculum, especially reform oriented curricula, teachers adapt their knowledge and in the process develop new content and pedagogical content knowledge in order to cope with the demands of the new curriculum. In Ghana, in-service teachers are required to teach an integrated mathematics curriculum. While in the university, these teachers took mathematics courses on different aspects of mathematics not in an integrated manner. To be successful in teaching the integrated mathematics curriculum at the high school level, in-service teachers in Ghana have to adapt their knowledge. They are helped in most cases by new textbooks developed and revised since the 1987 educational reforms embarked on by the country and the school-level collaborations that exist among teachers in high schools in the country. In addition, the Mathematical Association of Ghana organizes annual conferences at the regional and district level, as well as biennial conferences at the national level. At these conferences teachers and mathematics educators share their research and best practices and provision is made for professional development on areas where teachers have earlier indicated they need help with. With these changes and activities constantly going on, teachers could be engaging in various forms of adaptation that may have improved their content and teaching knowledge beyond the level at which they were when they were in college. It is therefore not surprising that in-service teachers outperformed all categories of university seniors in this study.

Among university students in Ghana, ANOVA revealed differences in the performances among students in the different majors. In general the mathematics majors performed significantly better than their counterparts majoring in statistics and mathematics education on items categorized to meansure each of the three hypothesized knowledge. It is unclear whether these differences existed before the different categories of students entered the university or whether the differences are the result of the type of courses they have taken at the university level. It is hoped that future research will take this into account in the design. If further research confirms that such differences existed before the mathematics majors and the mathematics education majors prior to their entry into the universities, then it is recommended that the mathematics education departments take steps to attract some of the best students in their area. If, on the other hand, further research reveals that the differences did not exist prior to their entry into university and that it is a result of the type of courses they have taken at the university level, then there is the need to examine the argument of value added by teacher education. In the event of the latter, it could be argued that, as is practiced in most US states, the value of teacher education is observable after students have been allowed to major in mathematics and then return for the teacher education or certification later after their undergraduate degree, instead of being allowed to take undergraduate degree in mathematics education. Between the statistics and mathematics education students, the statistics majors did slightly better than the mathematics education students. However, this difference was not significance at the .05 level.

RECOMMENDATIONS FROM THE STUDY

The conclusions drawn from this study have far-reaching implications for further studies into teacher knowledge especially in Ghana. The following options are recommended for further studies:

First, universities in Ghana have other mathematics-related programs from which students have exited into the field of teaching either through initial national service postings or sometimes due to the limited job opportunities available in the country. For instance, currently there are high school mathematics teachers who majored in various engineering programs or even in economics (with mathematics as a minor area of emphasis). This study did not involve students from the full spectrum of all the possible programs. The results of the study therefore apply to the selected major areas of mathematics, statistics and mathematics education and it is not known whether university students majoring in these other areas would compare differently with in-service teachers or with any of the other groups who took part in this study. Because research in the developing world has found teachers' subject matter knowledge as a better predictor of student performance than students' home-based factors (see Harbison and Hanushek, 1992; Mullens et. al., 1996), further research is needed to include all these groups. This is important because knowing how all the possible groups compare would help to provide a framework for investigating what experiences in their programs of study could be responsible for the trend observed. This, in turn would be useful for professional development of teachers and for improving pre-service mathematics teacher education in Ghana.

Second, the limitations imposed on this study due to the small number, especially of the participating in-service teachers call for the need to get more in-service teachers involved in further studies such as this. Extending fieldwork to cover a period of at least one year is one recommended option. Also, spending this extended time in fieldwork could improve the chances of involving a larger sample of in-service teachers in any future studies. Another option involves seeking enough funding to pay participants to get more of them involved. Taking such steps to increase the participation of more in-service teachers could help investigate how the number of years of teaching experience could improve or expand teachers' knowledge.

Finally, this study has found that among university seniors, there are marked differences in the level of the three types of algebra knowledge for teaching. It is not clear whether the differences in knowledge found in this study were the result of the differences in their university coursework or the differences in performance prior to entering the different programs at the university level. A longitudinal study that helps students' entry knowledge levels to be determined and the changes in them as they progress in their programs is needed to assess the effect of their experiences in the growth in their knowledge base. Findings from such a study could be useful in decisions about curriculum development, especially for the mathematics education students who are actually being prepared for the classroom, as well as for professional development of high school mathematics teachers in Ghana.

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