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What explains gender gaps in maths achievement in primary schools in Kenya?

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This paper aims to improve the understanding of classroom-based gender differences that may lead to differential opportunities to learn provided to girls and boys in low and high performing primary schools in Kenya. The paper uses an opportunity to learn framework and tests the hypothesis that teaching practices and classroom interactions explain gender gaps in maths achievement in Kenya. The data used is obtained from a cross sectional study involving video recordings of 70 lessons in mathematics, students' scores in a maths test and interviews with subject teachers in Kenyan primary schools randomly selected from six districts. Results show that gender gaps in maths achievement are more evidenced in the area of measurement. The gaps are more pronounced among low achievers in favour of boys. The most revealing finding is that entry achievement level is the main source of gender gaps in maths learning outcomes, implying that girls start at lower levels than boys and this gap is not closed by school. The policy implication to education is that boys have better chances of transition to secondary school and tertiary levels than girls, and consequently, there are broader gender disparities than can be closed by pro-gender education policies.

Keywords: gender; instruction; opportunity to learn; maths; teacher; gain score

Introduction

This paper examines gender differentials in mathematics performance in primary schools in Kenya. There exists a longstanding concern amongst governments, development partners and civil societies around gender parity. Research on gender differences in education outcomes will therefore contribute to the understanding of what contributes to such differences. This paper uses the scores of a Grade 6 curriculum-based maths test and video recorded classroom discourse to investigate gender differentials in opportunity to learn. It addresses the following two questions: (a) What gender gaps exist in maths curriculum areas and the cognitive levels the tasks demand?; and (b) Do maths instructional practices and classroom interactions contribute to gender gaps in maths achievement? In the first question the analysis focuses on maths curriculum outcomes and levels of cognitive demand of tasks; while in the second question the paper examines classroom interaction opportunities and support from the teacher provided to girls and boys. The hypothesis tested is that girls and boys are not provided with equal opportunities to learn maths while in the classroom, and this contributes to gender gap in maths achievement.

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Gender gaps in maths achievement

In the education literature, gender gaps in maths achievement have been widely studied, particularly in the US and Europe (see for example Fennema et al. 1998; Bevan 2001; VanLeuvan 2004; Gallagher and Kaufman. 2005; Zhu 2007; Hyde 2008; Azar 2010; Else-Quest Hyde, and Linn 2010). But this literature is not conclusive and it remains both controversial and debatable on whether gender gaps in maths achievement really exist and what the sources of this difference are. It seems that results vary with context and analytical approach. For example, in the US, Hyde et al. (2008) dismissed the perceived gender gap in maths after finding no difference in average performance between girls and boys – based on standardised maths assessment involving seven million students of Grade 2 through 11. According to Hyde et al. the notion that boys do better than girls in maths is simply a stereotype that has been around for decades. Azar (2010) seem to support the view of 'no gender gap' when she states that there is no indication that women cannot succeed in maths-demanding fields, though she admits that females continue to be under-represented in maths, science and engineering-related careers. Other studies in the US context by Else-Quest, Hyde and Linn (2010), VanLeuvan (2010), Plante, Protzko and Aronson (2010) and Hyde and Mertz (2009) also found little or no difference in maths achievement between boys and girls and conclude that female and male students have nearly equivalent maths achievement capacity and levels. Guiso et al. (2008) who, in a cross-national study, also found that the gender gap in maths performance in favour of boys disappears or reverses as culture-related gender differences diminish. This finding is also supported by Azar (2010), who argues that if a gender difference in maths performance exists, it is small and only affects specific areas of maths skills at higher levels.

Conversely, there is literature that confirms and supports the existence of gender gaps in maths performance. The work of Halai (2010), Stephen, Ceci and Williams (2010), Plante, Protzko and Aronson (2010), Wiliam (2010), Machin and Pekkarinen (2008), Zhu (2007) and Gallagher and Kaufman (2005) are examples. A review of literature from different studies on gender gaps in achievement by Gallager and Kaufman (2005) concluded that girls score lower than boys on standardised tests of maths. They argue that such gaps are real and very significant, as test scores determine entrance to higher training and, by extension, to future success. This argument is supported by the work of Nelson and Brammer (2010) who found that in mathematically intensive fields, women's progress is less dramatic. For example, in the top 100 US universities, women occupy between 9% and 16% of tenure-track positions in maths intensive fields. In Tanzania, female enrolment in the academic year 2005–2006 in engineering related first degree courses in the University of Dar es Salaam ranged between 11% and 20%, and this was after lowering the cut-off points for female candidates (Benjamin 2010). After reviewing a large body of relevant literature on gender gaps in maths problem-solving, Zhu (2007), concludes that the literature has consistently reported that boys do better than girls in standardised maths test but only among high-ability students. This conclusion is consistent with an earlier finding by Bevan (2001) who posits that gender gaps in maths attainment are largely concentrated amongst the highest achievers. Fennema et al. (1998) found no significant difference between boys' and girls' performance in maths tasks among early graders (1–3), particularly in number facts, operations and even in non-routine maths tasks, a finding that is consistent with that of Wasanga, Ogle and Wambua (2010) in Kenya. However, Fennema's study acknowledged that boys solved more extension problems that required flexibility in thinking.

The debate on gender in Africa is less about achievement compared to the literature and debate in the US. The literature in Africa is mainly concentrated on analysis of gender parity in terms of enrolment, but not in terms of achievement gaps. However, the few studies done thus far seem to support the view that gender gaps in maths achievement exist. For example, using SACMEQ data for the 15 countries participating in the study, Saito (2010) found that the set of countries where boys performed significantly better than girls in mathematics in 2000 (Tanzania, Kenya, Malawi and Mozambique) were also countries where boys performed better than girls in 2007. The author further asserts that between 2000 and 2007, the directions in gender differences in maths achievement were consistent. A further analysis of gender inequalities among the participating countries show that the set of countries where boys outperform girls in maths (Tanzania, Kenya, Malawi and Mozambique) have among the lowest gender-related development index (GDI) of between 0.365 and 0.472; the set of countries where girls outperformed boys in maths (Seychelles, Mauritius, Botswana and South Africa) had among the highest GDI of between 0.559 and 0.781 (UNDP 2005). This is consistent with the finding by Guiso et al. (2008) that used PISA results to show that gender gaps in maths achievement and the level of gender inequality in a society were associated.

In the rural South Africa's KwaZulu-Natal province, a study by Muthukrishna (2010) found gender gaps in Grade 6 maths achievements in favour of girls. According to Muthukrishna, the main factors associated with the gender gaps in maths included the issue of masculinities, classroom practice and attitudes to learning maths. Using Grade 6 SACMEQ II datset for Kenya, Onsomu, Kosimbei and Ngware (2006) found large (27 points) differences in gender performance in maths, in favour of boys. In a study of maths performance in different types of secondary schools in Kenya, Bosire, Mondoh and Barmao (2008) found that streaming based on gender improved maths achievement, and particularly for girls. The study recommended institutionalisation of a streaming policy as an intervention for improving girls' performance in maths.

What factors might explain gender gap in maths performance?

If gender gap in maths achievement do indeed exist, what are the factors that explain it? Zhu (2007) asserts that gender differences in maths result from a combination of psychological, environmental and cultural factors. This means that instructional practices can play a role in shaping problem-solving abilities among boys and girls. Furthermore, educationists have argued that the differences emerge as a result of attitude, the influence of role model and stereotyping, while on the other hand, psychologists explain the differences using cognitive theory (see for example Azar 2010; Hyde 2008; Zhu 2007; Gallagher and Kaufman 2005; Bevan 2001). From these studies, four main factors emerge – attitudes, stereotyping, teaching and learning styles, and spatial ability.

Studies have shown that perceptions of mathematics can partly explain gender gaps in maths achievement. For example, in the US, APU (1981) found that almost 20% more girls than boys considered themselves lucky if they performed well in a maths test. According to Bevan (2001), the main factors that explain pupils' perceptions of maths are: expectations; types of activities included in the maths curriculum; and the prevailing stereotypes. The effects of stereotypes on girls' school performance in maths are well-captured in the literature by the works of Plante, Protzko and Aronson (2010), where they explore the stereotype paradigm. According to Plante et al., one of the contributing factors to gender stereotypes on girls' maths performance is the 'maths anxiety' of their female teachers. Plante's study showed girls' maths performance decreased as a function of their female teachers' maths anxiety; boys maths performance remained unaffected. In Pakistan, Halai (2010) found that teachers consider boys to be 'better mathematicians' (54), arguing that boys are inherently better at maths while girls are well behaved and work hard. When such stereotypes find their way into classroom practices, they are likely to be reflected in learning outcomes to the detriment of girls.

Drawing from developmental psychology, Becker (1995) explores the various ways of knowing in mathematics among females. He concluded that girls are traditionally denied the opportunity to learn maths in ways that would help them to succeed due to styles of teaching and learning that are not congruent with how girls approach maths tasks. Robin (2001) supports this view when he asserts that girls are 'connected' thinkers who require exploration of context and relationship when doing maths. This view is also shared by Head (1995) who asserts that, on the one hand, girls prefer cooperative, supportive working environments, while, on the other hand, their male counterparts opt for competitive and pressurised environments. Traditional models of instructional delivery that encourage disjoined concepts and abstract development of maths disciplines are therefore inconsistent with what would benefit girls in maths learning. According to Hyde, Fennema, and Lamon's (1990) meta-analysis of 100 studies, gender gaps in maths performance were minimal but gender differences in maths problem-solving strategies were large. These differences were attributed to cognitive abilities, speed of processing information, learning styles and socialisation (see for example Royer and Garofoli 2005; Zhu 2007). Gender differences in solving maths problems have been reported even among early grade learners. For example, Fennema et al. (1998) report that first grade girls were more likely to use manipulative strategies while first grade boys were more likely to use retrieval strategies in solving maths problems. Fennema et al. continue to argue that girls are more likely to use concrete strategies while boys will use more abstract strategies.

Related to the strategy used is the level of student cognitive abilities. According to Zhu (2007), higher ability students tend to solve problems using more spatial processes, while lower ability students adopt a more analytical approach. Other studies show that there is a link between classroom instruction and choice of strategy. For instance, in a meta-analysis involving 487 studies on maths problem-solving, Hembree (1992) found a positive impact on task performance that resulted from classroom instructions.

From the literature reviewed, gender differences in mathematics is clearly an area that remains controversial and requiring further research. This is particularly so because no single cause can be attributed to gender differences in maths performance. Nonetheless, the available literature, mainly from developed countries, has provided avenues that if further investigated could shed more light on the genesis of the differences, though some studies insist that no such differences exist. It is clear from this literature that where gender gaps in maths are found, they result from many different factors that have environmental, psychological and cultural origins. It has also been argued that girls and boys may process the same mathematical ideas differently, using different problem-solving strategies. Equitable opportunity to learn maths in the classrooms may not happen without specific attention to the underachieving groups. It is therefore important to continue to engage in debate that explores ways to deepen the understanding of how equity in maths performance can be achieved, particularly in geographical regions where little is known on the topic. The aim of this paper is to add to this literature based on empirical study undertaken in schools in Kenya.

Methods

Selection of schools and participants

Six districts were selected for inclusion in this cross sectional study. They included those that had consistently been ranked in the bottom 10% in Kenya Certificate of Primary

Education (KCPE) examination league tables over the past four years; those that had been consistently ranked in the middle, and those that had been consistently ranked in the top 10% over the same period. In total, 72 schools were selected, with 12 in each of the six districts. The selection of the schools was random within the top 20% and bottom 20% in each of the six districts. The KCPE annual league tables is released by district and by school so that it is possible to see which districts dominate the top performance and within each district it is possible to see which schools dominate and which ones lag far behind. School location does matter, and therefore, a further selection criterion ensured a mix of rural, suburban, and urban schools. Overall, the study can be considered as being nationally representative as the six districts cut across much of Kenya's geography. In total 2436 pupils were reached for the study, with 1299 boys (53.3%) and 1137 girls (46.7%). For this paper, two schools were eliminated because one was boys-only and the other closed down after the first round of data collection, preventing the second round. The sample for this paper is 70 schools in six districts with a total of 1890 pupils who could be traced in Round 2 and who thus provided data for both rounds. After the second round of test administration, it was thus possible to compute gain score for 1907 pupils (i.e., their score in Test Round 2 minus their score in Test Round 1).

Data collection instruments

Three survey instruments and an assessment tool were developed and pre-tested to improve validity and reliability. The three survey instruments are: a head teacher questionnaire that solicited information on school management, staffing, enrolment, and parental participation in school affairs; a teacher questionnaire that solicited bio-data, qualification and training, discipline, and syllabus coverage information; and a pupil questionnaire that collected information on socio-economic backgrounds of the Grade 6 learners and their perceptions of the school environment. This questionnaire was administered to each of the Grade 6 pupils in the selected schools. The assessment tool was a mathematics test for Grade 6 pupils that assessed their competencies in the curriculum areas of number concepts and operations, patterns and algebra, measurements, geometry and basic statistics. The same test was administered in all schools during the two rounds of data collection that were carried out within a span of 10 months. Lesson observations were conducted using a video camera and an observation checklist. Overall, the questionnaires return rate was very good at 98.6% because these were collected on the spot by the field researchers and their supervisors. Prior consent had been sought from the Kenyan Ministry of Education; from head teachers of the participating schools, who also signed off on behalf of parents as is normally the practice in Kenya (but a letter was sent to parents through the head teachers informing them of this research); and from the teachers. The overall ethical procedure was approved by the Kenya Medical Research Institute (KEMRI), which is one of the bodies that has oversight on research ethics in Kenya.

Video analysis

A video analysis rubric was developed to analyse systematically the video recordings. The procedure draws upon classroom interaction research, notably the work of Chesterfield (undated), Sorto et al. (2009) and a classroom interaction study in South Africa (Carnoy et al. 2008). The rubric was adapted to suit the study objectives by splitting the broad activities into readily observable tasks, and including additional questions to assess the overall pupil–teacher interactions and classroom physical environment. The rubric was also pre-tested to improve reliability. All video-recorded lessons were analysed using a systematic observation and timeline analysis. The recording was made after teachers had consented. According to Ackers and Hardman (2001), this kind of analysis is appropriate because one requires a way of synthesising the mass of recorded lesson discourse in a systematic way to identify and quantify clear patterns of teacher-pupil interactions. In addition, a form to capture pupil seat position was also developed and used in conjunction with the video recording to capture classroom seating arrangements. The video analysis techniques also allow triangulation with the observation data to achieve greater validity and reliability in the analysis of classroom observation data. To improve on the quality of lesson recordings, four research assistants were trained in the optimal ways of filming using high quality video equipment. The assistants made several mock recordings in some non-selected schools and the recordings were used to train and improve the quality of filming. Two teacher trainers with extensive experience analysed the videos with an external validation of their analyses conducted by an expert in video analysis from another ongoing African classroom-based research study in Southern Africa. The two internal experts first analysed each video separately and then jointly, each providing his/her interpretation of what was observed and comparing their analyses. The analysis by the external expert did not significantly differ from that of the internal experts, which gave confidence in the internal analysis of the videos.

Variable descriptions

Gender gap in maths achievement. Refers to the observed disparity on standardised maths test scores between boys and girls. The gap was also measured by gain score – the difference between scores in Rounds 1 and 2 of test administration.

Maths curriculum outcome areas. Refers to the mathematical areas in which learners are expected to develop numeracy skills. Five curriculum outcome areas were identified from the Kenya maths curriculum (Government of Kenya. 2002):

(1) Number concepts and operations (24 test items): This included counting, grouping, recognising, ordering, reading and writing whole and decimal numbers, and fractions. This curriculum outcome area also required learners to learn the concept of place value. Learners are also expected to develop the ability to perform the four basic operations – add, subtract, multiply and divide – and be able to extend these basic operations to problem-solving strategies.
(2) Patterns and algebra (four test items): In this curriculum outcome, learners are expected to develop a positive attitude towards maths and make good use of their time by relating to maths skills as demonstrated in making patterns and models, solving puzzles and maths games, and relating maths to desirable experiences in everyday life.
(3) Measurements (five test items): In this curriculum outcome, learners are expected to develop skills of measurement, approximation and estimation. This area includes learning how to measure length, area, volume, capacity, mass, time, money and temperature. Learners are also expected to know how to convert one unit of measurement to another, solve maths problems involving various units of measurement, estimate quantities and approximate numbers.
(4) Geometry (four test items): Under this curriculum outcome, students develop special concepts and the ability to use them. They categorise objects of different shapes, make geometrical constructions, scale drawing, and apply spatial concepts in everyday life.
(5) Basic statistics (three test items): In basic statistics, students acquire techniques of collecting, representing and interpreting data.

Levels of cognitive demand of maths tasks. Stein et al. (2000, 16, 21) classify lower (1 and 2) and higher (3 and 4) levels of cognitive demand of maths tasks to as follows:

- Memorisation (low level): recollection of facts, formulae, or definitions (12 test items).
- Procedures without connections (low level): performing algorithmic type of problems that have no connection to the underlying concept or meaning (five).
- Procedures with connections (high level): use of procedures with the purpose of developing deeper levels of understanding concepts or ideas (11).
- Doing mathematics (high level): complex and non-algorithmic thinking where students explore and investigate the nature of the concepts and relationships (12).

Using the description of curriculum outcome areas and levels of cognitive demand of test items and questions asked during instructions, as described in the section on variables above, each test item and question asked to a leaner was mapped on to the curriculum outcome area and/or a level of cognitive demand of a maths task for the purposes of analysing gender gaps in performance across curriculum areas and engagement during instruction.

Results and discussion

Table 1 presents the mean score for Test 1 and gain score for both boys and girls in different mathematics curriculum outcome areas and levels of cognitive demand of the test items. In this table and in all the others, significance refers to statistical significance. In top performing schools, the mean score for boys in Test 1 is significantly higher on test items in the

Table 1. Gender differences in maths achievement by curriculum outcome areas and levels of cognitive demand of test items.

				Gain score	
Mean score, Test 1	Max score	Girls	Boys	Girls	Boys
Top schools					
Number concept	24	14.36*	14.75	2.74	2.29*
Patterns & Algebra	4	1.37	1.42	0.91	0.89
Measurement	5	1.88*	2.26	0.63	0.67
Geometry	4	1.92	1.96	0.61*	0.79
Basic statistics	3	1.21	1.24	0.95	0.87
Memorization	12	6.64*	6.99	1.19	1.31
Performing routine procedures	5	2.73	2.81	1.02	0.96
Performing complex procedures	11	5.59*	5.79	1.44	1.15*
Problem-solving	12	5.78*	6.03	1.81	1.58
All items	40	20.74	21.63	5.21	5.57
Bottom schools					
Number concept	24	11.37	11.45	2.23	2.35
Patterns & algebra	4	1.01	1.05	0.73	0.78
Measurement	5	1.17*	1.45	0.33*	0.61
Geometry	4	1.27	1.27	0.46	0.48
Basic statistics	3	0.82	0.87	0.42	0.43
Memorization	12	5.04	5.23	1.07	1.21
Performing routine procedures	5	2.02*	2.15	0.73	0.64
Performing complex procedures	11	4.33	4.23	1.12	1.28
Problem-solving	12	4.25	4.44	1.17	1.33
All items	40	15.64	16.09	5.28	4.51

Notes: * Statistically significantly lower.

curriculum areas of number concepts, measurements, memorisation and problem-solving levels of the cognitive demand of a task. In the bottom performing schools, the mean scores for boys in Test 1 are higher in curriculum areas of measurements, and among items requiring performance of routine procedures. From these statistics, gender gaps in maths achievement are evident in the curriculum area of measurement regardless of school rank, while under the levels of cognitive demand of the test item, in top schools boys scored higher than girls in items requiring problem-solving, that is, high level demand tasks. In bottom KCPE performing schools boys scored higher than girls in one of the lower level cognitive demands (performing routine procedures).

On gain score, in the top schools, girls significantly gained more in questions linked to the curriculum area of number concepts, while boys did better in geometry; under the levels of cognitive demand, girls gained more in performing complex procedures of maths tasks in spite of their initial score being lower on such items. In the bottom schools, boys had significantly higher gain scores on test items related to measurement.

The conclusions that can be drawn from this analysis are:

(1) Boys did better in the curriculum area of measurement and even achieved higher gains over time, hence widening achievement gaps in this area. A maths test with a higher proportion of items on measurement is therefore likely to widen gender gaps in maths achievement in favour of boys.
(2) Boys did better on items that require problem-solving/doing maths. Such items require abstract thinking to be resolved.
(3) Girls are good at maths tasks requiring procedures. Girls who are high achievers will do better than their counterparts (boys) in performing tasks requiring complex procedures, while low achieving girls will do better than low achieving boys in tasks requiring routine procedures.

The results confirm and support the debate on the existence of gender gaps in maths achievement as reported by Halai (2010), Stephen, Ceci and Williams (2010), Plante, Protzko and Aronson (2010) and Wiliam (2010). However, the findings go a step further to document not only the curriculum areas but also the levels of difficulty of maths tasks that can exacerbate gender gaps in maths achievement. Boys scored higher than girls on most items that required a higher level of cognitive demand, while girls scored better in items requiring procedures. Therefore, the finding is similar to that of Fennema et al. (1998) who also asserts that gender gaps in maths will not exist if maths tasks are on number facts, operations and even in non-routine tasks. It is those tasks that require flexibility in thinking that lead to gender gaps in maths achievement.

To have a better understanding of gender differences on the improvement of different aspects of pupils' cognitive demands, the results were adjusted for teachers' gender. In the top KCPE performing schools, being taught by a male teacher helps the girls to improve on test items related to number concepts as well as tasks that demand high level cognition (problem-solving). But in the bottom schools, girls gained more in items on curriculum areas of number concepts and geometry, and on test items requiring performing routine procedures when taught by a male teacher. In top schools, boys performed significantly higher on basic statistics but lower in patterns and algebra, and in items requiring the lowest level of cognitive demand (memorisation) when taught by a male teacher. But in bottom schools, boys taught by a male teacher gained more on test items related to number concepts, and performing complex procedures and problem-solving. When taught by a male teacher, boys in the bottom schools gained most (three out of five) in curriculum outcome areas than boys from top schools, and only in one (memorisation) level of cognitive demand.

What can be deduced from these statistics is:

(1) When girls are taught maths by a male teacher, regardless of the school, they score significantly higher than boys in number concepts, which is a basic curriculum outcome area, upon which all other maths topics are anchored, and they also do well in tasks that require procedures. Girls in bottom schools score higher than boys in items requiring routine procedures, while those in top schools do better in items requiring complex procedures.

(2) When boys are taught by a male teacher, the general performance of a school matters. For instance, in top schools, they perform well in basic statistics but worse in patterns/algebra, and in test items requiring the lowest cognitive level. In bottom schools, boys perform well in number concepts and in items requiring complex procedures and problem-solving. Although the literature is silent on how the gender gap is influenced by the interaction of a teacher's gender and curriculum outcome area, one plausible explanation for this finding is that male teachers are thought to be 'better' maths teachers compared to female teachers. This in turn may affect the attitude of girls towards maths.

Table 2 compares gender gaps in maths achievement for pupils in the lowest wealth quintile (WQ1) and highest (WQ5) wealth quintiles. From Table 2, pupils in wealth quintile 5 had better scores compared to pupils in quintile 1. After disaggregating data by wealth quintiles, boys in top schools had higher Test 1 scores than girls in almost all the curriculum areas and levels of cognitive demand under consideration – except in two curriculum areas of patterns and algebra, and geometry. However not all the differences were statistically significant. In particular, boys performed significantly higher than girls on test items related to the curriculum area of number concept and items requiring performing complex procedures and problem-solving. On gain scores, boys from the top schools gained significantly more than girls on measurement, geometry and memorisation.

In bottom schools, boys in WQ5 scored higher in all curriculum areas and levels of cognitive demand with measurement, and items requiring knowing (low level) and problem-solving (high level) being statistically significant. From these statistics and Table 2, clear differences in maths achievement emerge after disaggregating data by household wealth quintiles. Disaggregating data by social backgrounds allows comparison of gender gaps in maths within socio-economic groups. The analysis shows that gaps still exists even within the same socio-economic class, an indication that pupil background may not explain existence of gender gaps in maths.

Table 3 shows gender gaps in maths performance across curriculum outcome areas and levels of cognitive demand of test items, while taking pupils academic ability into account. To investigate gender gaps according to achievement quintiles based on test 1 scores, achievement quintiles were separately computed for boys and girls while controlling for school rank (top/bottom), on the one hand (labelled as achievement quintile type I), and without controlling for school rank, on the other hand (labelled as achievement quintile type II). Comparisons are then made using the gain score. For the purposes of understanding gender gaps across academic achievement quintiles, data on boys and girls is presented from achievement quintile 1 (lowest achievement quintile,) and quintile 5 (highest achievement quintile,). Boys in the top schools and in gained more in two curriculum areas and one level of cognitive demand of the test items after controlling for school rank. Even when school rank is not

Table 2. Gender differences in maths performance within the lowest and highest wealth quintiles.

		Gain score							
		W1		W5		W1		W5	
Mean score, Test 1	Max score	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Top schools									
Number concept	24	15.78	15.70	13.88	12.65*	2.62	2.67	1.93	1.67
Patterns & algebra	4	1.61	1.44	1.36	1.48	0.78	0.97	0.78	0.35
Measurement	5	2.62	2.14*	1.81	1.54	0.69	0.75	0.71	0.20*
Geometry	4	2.35	2.28	1.54	1.58	0.86	0.65	0.70	0.02*
Basic statistics	3	1.53	1.41	1.07	0.86*	0.84	0.94	0.82	1.04
Memorization	12	7.84	7.35*	6.07	5.86	1.28	1.21	1.37	0.33*
Performing routine procedures	5	3.13	3.04	2.50	2.32	1.11	1.02	0.77	1.02
Performing complex procedures	11	6.34	6.14	5.53	4.99*	1.14	1.50	0.88	0.70
Problem-solving	12	6.58	6.43	5.57	4.95*	1.80	1.88	1.34	1.05
Bottom schools									
Number concept	24	11.64	11.88	11.75	11.04	2.46	1.87	1.97	1.98
Patterns & algebra	4	1.24	1.07	0.97	0.85	0.36	0.76	0.95	0.67
Measurement	5	1.58	1.32	1.48	1.00*	0.45	0.23	0.70	0.61
Geometry	4	1.52	1.34	1.32	1.23	0.37	0.59	0.37	0.31
Basic statistics	3	0.70	0.80	0.92	0.85	0.63	0.39	0.45	0.54
Memorization	12	5.70	5.17	5.29	4.78*	0.96	1.00	1.07	1.17
Performing routine procedures	5	2.24	2.10	2.15	2.06	0.64	0.83	0.92	0.76
Performing complex procedures	11	4.45	4.32	4.40	4.15	1.09	1.39	1.13	0.81
Problem-solving	12	4.27	4.83	4.60	3.96*	1.57	0.79	1.12	1.16

Notes: * significantly lower.

controlled for in this computation of achievement quintiles, a similar pattern is observed but significant gender gaps, in favour of boys, are observed in three of the four levels of cognitive demand of test items. In bottom schools, in ,boys gained significantly more than girls in two curriculum outcome areas (pattern and algebra, and measurement) and in one area (memorisation) that required low level cognitive demand of test items.

From these statistics and Table 3, a clear pattern is emerging. In top-performing schools, gender gaps exist among low achievers, while in bottom-performing schools gender gaps in maths achievement exist among the top achievers. These different patterns could be as a result of school level factors. Generally, most of the high achievers are found in top schools. The high achievers in bottom schools may not necessary be categorised as high achievers if their performance is compared to those of high achievers in top schools. The conclusion is that gender gaps in maths are more common among low achieving students. This interpretation of the findings is not consistent with the literature. For example, Zhu (2007) concluded that boys do better than girls in standardised maths test but only among high ability students; while Bevan (2001) posits that gender gaps in maths attainment are largely concentrated amongst the highest attainers. In this case the reverse is true, where the performance difference is wider among low performing groups.

Table 3. Gender gaps by achievement quintiles Achievement quintile levels Achievement quintile type I.

		Achievement quintile levels							
		Achievement quintile type I				Achievement quintile type II			
	Max score	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Top schools									
Number concept	24	3.22	2.71	1.66	2.10	3.13	2.64	1.35*	1.98
Patterns & Algebra	4	0.69	0.80	1.08	1.09	0.81	0.70	0.96	0.88
Measurement	5	1.09	0.49*	0.67	0.61	0.94	0.44*	0.72	0.48
Geometry	4	1.23	0.77*	0.70	0.70	1.13	0.68*	0.87	0.65
Basic statistics	3	0.45	0.75	1.09	1.08	0.71	0.70	0.98	1.08
Memorization	12	2.29	1.58*	0.95	0.97	2.24	1.40*	0.76	0.68
Performing routine procedures	5	1.05	0.92	1.09	1.19	0.94	0.91	0.92	1.18
Performing complex procedures	11	1.76	1.31	0.97	1.25	1.79	1.24*	0.93	1.22
Problem-solving	12	1.77	1.36	1.38	1.49	1.81	1.23*	1.13	1.24
Bottom schools	Max score	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Number concept	24	2.82	2.88	2.00	2.30	3.16	3.35	1.75	1.73
Patterns & algebra	4	0.67	0.78	1.06	0.25*	0.81	1.00	0.89	0.45
Measurement	5	0.56	0.46	1.21	0.38*	0.34	0.75	0.70	0.33
Geometry	4	0.50	0.57	0.59	1.50	0.53	0.68	0.52	0.53
Basic statistics	3	0.35	0.45	1.33	0.71	0.28*	0.66	0.90	0.69
Memorization	12	1.40	1.53	1.68	0.64*	1.57	2.03	1.00	0.58
Performing routine procedures	5	0.58	0.74	1.13	1.00	0.67	0.89	0.94	1.00
Performing complex procedures	11	1.58	1.65	1.04	1.67	1.51	1.99	0.70	0.69
Problem-solving	12	1.28	1.13	1.67	1.71	1.38	1.59	1.65	1.33

Notes: *Significantly lower.

Table 4 presents the levels of cognitive demand of questions asked to pupils in Grade 6 during maths lessons. The questions were mapped into the four levels of cognitive demand of maths tasks as a way of assessing their levels of difficulty. Easy questions were placed in Levels 1 and 2: Level 1 was knowing or memorisation, and Level 2 questions required the pupil to perform a routine procedure or conceptualise without connection. Difficult questions were placed in Levels 3 and 4: Level 3 questions required the pupil to perform a complex procedure or procedures with connections in order to get a solution, while Level 4 comprised problem-solving or doing maths. In all the questions that were asked, none qualified as a Level 4 question. Out of all the questions asked to pupils during the maths lessons, 68% were simple questions that required the learner to have memorised or known the fact. For example, *teacher*: 'How do you get the area of a circle?'; *pupil*: 'pie r-squared'. Girls were given fewer (55%) opportunities to respond to low level questions compared to boys (59%), or even the whole class (77%). From the results it is evident that the whole class was more engaged in answering simple questions. From these statistics, two observations stand out clearly: (1) most teachers do not engage their learners in questions that require critical

Table 4. Level of difficulty of question asked by the teacher and gender of respondent.

	All schools (%)				Top schools (%)			Bottom schools (%)		
Question level*	Boys	Girls	w. class	Total	Boys	Girls	w. class	Boys	Girls	w. class
Level 1	59.0	54.7	77.0	68.7	58.1	58.2	74.8	60.1	51.1	78.5
Level 2	39.2	44.3	22.2	30.3	39.3	40.5	24.4	39.2	48.0	20.8
Level 3	1.8	1.1	0.7	1.0	2.6	1.3	0.8	0.7	0.9	0.7

Notes: * Level 1 = memorization; Level 2 = procedures without connection; Level 3 = procedures with connection; and, Level 4 = problem-solving; There were no questions in Level 4.

thinking or problem-solving skills; (2) maths instruction discourse is dominated by simple and repetitive questions and answers. Though most of the tasks in a lesson were simple and repetitive, and therefore not promoting flexibility in thinking, they are nevertheless an indication of the level of engagement during the lesson. From the data, it would appear that a higher proportion of boys than girls were involved during the lesson.

Further analysis revealed that 58% of boys and girls in the top schools participated in answering memorisation questions compared to 60% and 51% in the bottom schools. The whole class participation in responding to low level questions was more common among the bottom schools (78.5%) compared to the top schools (74.5%). A higher proportion of girls than boys in both the bottom and top schools participated in responding to questions requiring procedures with no connections (Level 2). However, the trend changed in those questions that required procedures with connections, with a higher proportion (2.6%) of boys in the top schools, for instance, engaged in responding to Level 3 questions compared to girls (1.3%). This finding is similar to that of Halai (2010) who finds that the pattern where girls tend to participate more in simpler tasks (procedures without connections – Level 2) and less in high level tasks (procedures with connections) is as a result of the difference in problem-solving strategy between boys and girls reinforced by stereotyping. Literature reviewed suggests gender differences in maths problem-solving strategies are large and can be attributed to speed of processing information, learning styles and socialisation (Zhu 2007; Royer and Garofoli 2005; Hyde 1990). According to Fennema et al. (1998), girls are more likely to use concrete strategies while boys will use more abstract strategies. Such differences in the choice of strategy may explain the gender gaps in performance across tasks of different levels of cognitive demand, and can be reinforced by teachers.

Table 5 presents the distribution of pupil responses by gender and follow-up moves/feedback from the teacher. Teacher feedback is categorised into five levels: very encouraging feedback (e.g., very good, keep it up, well done); encouraging feedback (good/OK/fine/correct/right/yes, try again, a good trial or teacher affirms the response); neutral feedback (teacher probes, teacher gives the answer, teacher proceeds to confirm the correctness of the response from a pupil or class); discouraging feedback (teacher proceeds to ask another pupil to respond to the same question, teacher says nothing and proceeds to another issue or task); and, very discouraging feedback (incorrect/not right/no, poor/very poor/wrong).

Overall, a higher proportion (83%) of boys received very encouraging feedback compared to girls (73%) when they answered a verbal question correctly. However, the trend changed when the task was a demonstration, with 23% of girls receiving very encouraging feedbacks for a correct demonstration compared to 13% of the boys. Demonstration involved a student going to the chalkboard to solve the task in front of the whole class. For both boys and girls, incorrect answers received about 50% of the mild negative feedback and 40% of teacher's intervention. No girl received a negative feedback when they gave the

Table 5. Teacher follow-up moves after individual responses to a question.

	Very encouraging		Encouraging		Neutral		Discouraging		Very discouraging	
All school	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Correct verbal	82.6	73.1	90.0	90.9	37.2	35.1	40.4	31.8	11.1	0.0
Correct demo	13.0	23.1	3.9	3.6	13.2	24.7	7.5	10.6	0.0	0.0
Incorrect verbal	4.4	3.9	4.9	4.4	43.4	29.9	38.4	44.7	88.9	86.7
Incorrect demo	0.0	0.0	0.0	0.4	5.4	9.3	7.5	1.2	0.0	13.3
No response	0.0	0.0	1.2	0.8	0.8	1.0	6.2	11.8	0.0	0.0
Top school										
Correct verbal	86.7	81.3	88.4	91.5	41.3	34.7	49.4	44.4	14.3	0.0
Correct demo	6.7	18.8	5.8	4.2	14.7	32.7	2.4	6.7	0.0	0.0
Incorrect verbal	6.7	0.0	5.2	2.5	33.3	16.3	36.1	35.6	85.7	66.7
Incorrect demo	0.0	0.0	0.0	0.9	9.3	16.3	6.0	0.0	0.0	33.3
No response	0.0	0.0	0.6	0.9	1.3	0.0	6.0	13.3	0.0	0.0
Bottom school										
Correct verbal	75.0	60.0	91.8	90.3	31.5	35.4	28.6	17.5	9.1	0.0
Correct demo	25.0	30.0	1.9	3.0	11.1	16.7	14.3	15.0	0.0	0.0
Incorrect verbal	0.0	10.0	4.4	6.0	57.4	43.8	41.3	55.0	90.9	100.0
Incorrect demo	0.0	0.0	0.0	0.0	0.0	2.1	9.5	2.5	0.0	0.0
No response	0.0	0.0	1.9	0.8	0.0	2.1	6.4	10.0	0.0	0.0

correct answer, while 11% of boys received very discouraging feedbacks even when the response was correct.

Stratifying the results according to school rank gave more interesting findings. For example, there was more 'very encouraging' feedback among the top schools compared to the bottom schools. In particular, results from both the top and bottom schools revealed that boys received higher proportion of very encouraging feedback compared to girls. In the top schools, about 86% of the correct responses by boys received very encouraging feedback compared to 81% of the girls. In the bottom schools, 75% of correct responses by boys received very encouraging feedback compared to 60% for girls. On correct demonstration, results from both the top performing and bottom performing schools show that girls received more very encouraging feedback compared to boys. For incorrect answers among the top schools, boys received higher proportion of very encouraging feedback compared to girls. However, among the bottom schools girls received very discouraging feedback when they answered incorrectly, an indication that girls in the bottom schools may be getting less support in maths from their teachers. Teacher follow-up moves are part of instructional practices within a classroom. On the one hand, students who get positive feedback feel motivated to learn and their achievement may improve. On the other hand, constant negative feedback may discourage individual learners from participating in classroom discourse and hence they may lose the opportunity to learn. If girls are given more encouraging follow-up moves than boys, then this is likely to lead to higher scores among girls. This argument is supported by Zhu (2007) who argues that gender differences in maths achievement are due to a combination of factors including environmental - implying that instructional practices can play a key part in developing problem-solving abilities among boys and girls.

Table 6 presents the distribution (in percentages) of teachers' follow-up moves based on teacher's gender and pupil's gender. The table shows that the combined proportion of '*encouraging*' and '*very encouraging*' follow-up moves was higher among the male teachers (49.5%) compared to female teachers (46.8%). The majority of '*discouraging*' (combined with very discouraging) follow-up moves came from female teachers (40%), compared to male

Table 6. Teacher's follow-up move by teachers' and pupil's gender.

Teacher's follow-up	Teacher's gender		Pupil's gender		Whole class	Total
	Female	Male	Girls	Boys		
Very encouraging%	1.9	2.7	3.6	5.5	0.8	2.3
Encouraging%	44.9	47.8	51.0	52.9	42.5	46.3
Neutral%	12.1	13.9	20.1	20.5	7.9	13.0
Discouraging%	39.7	33.6	22.6	17.9	48.0	36.7
Very discouraging%	1.4	2.0	2.8	3.2	0.8	1.7
Total number	1,380	1,332	643	469	1,599	2,711

teachers (35.6%). A slightly higher proportion (53%) of boys received 'encouraging' feedback compared to girls (51%); whereas girls received a higher proportion of 'discouraging' feedback (23%) from teachers compared to boys (18%). These results indicate that female teachers are more likely to give 'discouraging' feedback and at the same time girls have higher chances of receiving 'discouraging' follow-up moves from the teachers. To have an idea of how classroom interaction was taking place in the classroom, four scenes are presented (see Appendix 1) that were captured in the videos. Appendix 1 presents a sample classroom interaction between a teacher and a pupil. This includes a question from the teacher, topic, pupils' response, teacher's judgment (correct/incorrect) and follow-up moves.

The analysis also shows that out of all the 1356 questions asked by male teachers, 26.4% and 18.3% were directed to girls and boys, respectively. The rest went to the whole class. The female teachers asked 1397 questions with 20.7% going to girls and 16.3% to boys, the rest went to the whole class. Overall therefore, girls were more involved in responding to maths tasks during instruction.

Regression results

Pupils' performance in measurement items have shown significant differences along gender lines in both top and bottom schools. To identify factors that might explain the observed gender differences in maths achievement, a linear regression model is fitted. The response variable is the difference between boys and girls on performance in measurement items based on gain score. The explanatory variables are: ratio of boys to girls on the following measures – the number of questions asked by the teacher during instruction, number of high level cognitive questions asked, pupils who received positive (encouraging and very encouraging) feedback from the teacher, preschool exposure, and pupils who reported receiving extra tuition for maths at home. Other covariates include teacher gender, class size, gender parity index within a class, availability of non-basic teaching materials in the classroom, school type (public/private), teacher scores in the maths test that was administered to teachers in this study, average age difference between boys and girls, teacher preparedness level, and school rank (top/bottom) in the four years of KCPE league table. Table 7 presents regression analysis results for all schools, and top and bottom schools. The results are based on 69 schools where 36 are from top schools while 33 are bottom schools. The model dropped one record due to missing information on the proportion of pupils with tuition.

The results show that initial pupil achievement level significantly contributes to differences in scores on measurement items between boys and girls across all the three models. For example, an increase in the initial mean achievement of a class reduces the differences in gain score on measurement test items between boys and girls. This implies that gender differences are likely to be minimal among high achievers, contrary to available literature. Among the

Table 7. Regression analysis results based on performance in measurement test items.

	All schools		Top schools		Bottom schools	
Number of observations	69		36		33	
Adj R-squared	0.271		0.246		0.431	
Root MSE	0.457		0.426		0.437	
	Coef.	P>t	Coef.	P>t	Coef.	P>t
Mean initial achievement level*	−0.64	0.000	−0.78	0.001	-0.95	0.002
Ratio of boys/girls asked difficult question	0.04	0.859	−0.21	0.649	0.43	0.155
Ratio of boys/girls on number of responses	−0.01	0.863	−0.14	0.124	0.06	0.508
Ratio of boys/girls with positive follow-up moves	0.01	0.736	−0.02	0.654	0.01	0.910
Teachers' gender (ref: Female)	-		-		-	
Male	0.02	0.864	−0.16	0.405	0.32	0.077
Non-basic teaching materials (ref: Not available)	-		-		-	
Available	−0.12	0.391	−0.18	0.304	−0.39	0.243
Class size	0.00	0.420	0.01	0.256	0.00	0.536
Dominant teaching activity (ref: Individ. work)	-		-		-	
Recitation	−0.11	0.510	−0.04	0.864	−0.30	0.362
Whole class	0.17	0.213	0.15	0.484	0.44	0.106
School type (ref: Private)	-		-		-	
Public	-0.30	0.061	-0.19	0.471	−0.53	0.100
Ratio of boys/girls with pre-school exposure	-0.20	0.086	-0.20	0.316	−0.30	0.124
GPI	0.16	0.244	0.28	0.230	0.33	0.187
Ratio of boys/girls with tuition	0.10	0.296	−0.05	0.817	0.10	0.528
Average age difference*	−0.08	0.359	0.16	0.233	−0.12	0.371
Teachers' scores	0.00	0.165	0.00	0.495	0.01	0.260
Teachers' preparedness (ref: inadequate)	-		-		-	
Adequate	0.26	0.171	0.44	0.193	0.41	0.216
Very adequate	−0.01	0.978	0.26	0.421	−0.19	0.471
	-		-		-	
	0.16	0.207				

Note: *refers to the difference between boys and girls.

bottom schools, the initial pupils' achievement level significantly reduces the differences between boys and girls in gain score by 95%. Psychologists explain such gender differences using cognitive theory, with factors such as learning styles and spatial ability being responsible for the difference (see for example Azar 2010; Hyde 2008; Gallagher and Kaufman 2005).

Teacher gender and school type have significant effects (at 10% significance level) on gain score in measurement items. For example, in bottom schools, being a male teacher increases the gain score gap in measurement items between boys and girls in favour of boys by 32%. Overall, studying in a government (public) school reduces the gap by 53% in gain score between boys and girls.

Conclusions and implications

The analysis of primary Grade 6 maths test scores in specific curriculum outcome areas shows the existence of gender gaps in mathematics achievement in primary schools in Kenya. The gaps are significantly different in the curriculum area of measurement. The conclusion is that gender gaps in maths are more common among low achieving students, in favour of boys. These findings are not consistent with what is known in the literature – that the gap is greater among high achievers or there is no difference at all. Demonstrated initial achievement/ability seems to be key determining factor of the gender gaps in maths in this study. Other factors that create a conducive environment for widening gender gaps in maths achievement include teacher follow-up moves.

The conclusion based on the evidence from this study is that the entry level academic achievement is the main contributor of gender differences in maths achievement in Kenyan primary schools. Teacher follow-up moves and curriculum delivery by teachers provide a context that can influence gender gaps. However, the gaps differ by school and learning contexts, academic achievement and wealth quintiles of the learners. These results imply that gender gaps in maths achievement exist in primary schools in Kenya and that they are manifested in different factors which combined lead to the persistence of low maths scores for girls.

There are three major implications of these findings that are relevant to the education policy and teaching practice in Kenya.

(1) If gender gaps go unchecked, they will continue to translate into inequalities in learning outcomes that lead to few girls making transition into secondary and tertiary levels of education. This means that girls will often lag behind boys in qualifications and skills and in employment opportunities. This has wide implications for the pro-gender development agenda in Kenya.
(2) If these gaps persist, girls will be disadvantaged while transitioning to secondary and tertiary education, and employment opportunities in science and engineering related fields, as higher scores in maths may be a basic requirement.
(3) If teachers become aware of the learner's entry academic behaviour and instructional practices that can lead or widen gender gaps in learning outcomes, then they have an opportunity to put in place mitigating strategies to minimise inequalities in learning outcomes. It may also help in reorganising teacher training practices that recognise the role of the teacher in promoting or closing the gender gap in maths achievement in Kenya.

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Appendix 1. A sample classroom interaction

Qn.	School	Topic	Teachers' question	Teacher's gender	Pupil's gender	Pupil's response	Follow-up move	Encouragement level	Sch. Rank
1	1	Measurement	What is circumference?	Male	Boy	Distance around a circular object	Correct	Very encouraging	top school
2	1	Measurement	So we have 17cm 6mm, this is equivalent to how many millimeters?	Male	Girl	176mm	Right	Very encouraging	top school
3	2	Shapes	What is the figure?	Male	Boy	Rectangle	Right	Very encouraging	Bottom school
4	2	Shapes	What is the formula?	Male	Girl	1/2*base *height	Correct	Very encouraging	Bottom school
5	3	Area	How do we calculate the area of a square	Male	Girl	Length*length	Incorrect responses	Discouraging	Bottom school
6	3	Area	What is the width of the smaller one?	Male	Boy	No response	No response	Discouraging	Bottom school
7	4	Numbers & fractions	What are we supposed to do when converting fractions do decimals?	Female	Girl	To multiply	Incorrect	Discouraging	Bottom school
8	4	Numbers & fractions	What are we supposed to do?	Female	Girl	Divide 3 by 5	Incorrect	Discouraging	Bottom school
9	5	Fractions	When we put 1 and 1/4 as an improper fraction, what are we going to get?	Female	Girl	4	Incorrect	Discouraging	Bottom school
10	5	Fractions	What do we do with the second fraction?	Female	Boy	Reciprocal	Incorrect	Discouraging	Bottom school
11	5	Fractions	What if we have mixed fractions, what are we going to do?	Female	Girl	You are supposed to divide	Incorrect	Discouraging	Bottom school