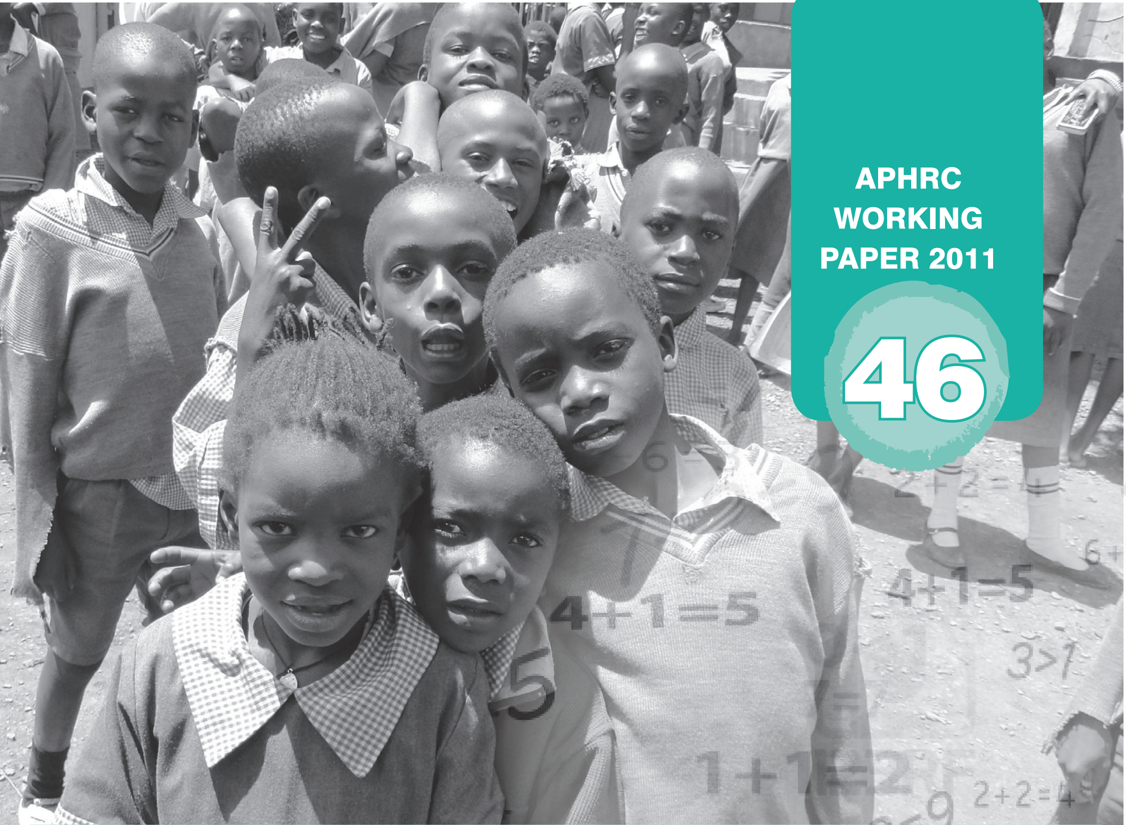

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What explains **gender gaps in math achievement** in primary schools in Kenya?

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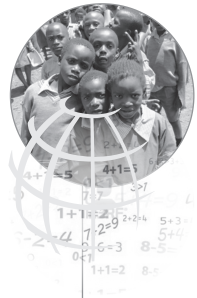

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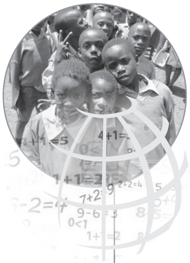


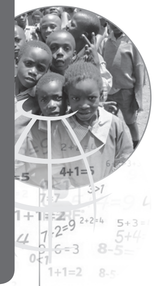
Abstract

In Kenya, girls are persistently outperformed by boys in math national examinations. This paper aims to improve our understanding of classroom-based gender differences that may lead to differential in opportunity to learn provided to girls and boys in low and high performing primary schools in Kenya, and ask whether this explains the persistent differentials in performance. The paper uses opportunity to learn (OTL) framework. It tests the hypothesis that teaching practices and classroom interactions explain gender gaps in math achievement in Kenya. The data used is obtained from video recordings of 70 lessons in Mathematics and interviews with subject teachers in Kenyan primary schools. Results show that gender gaps in math achievement are more evidenced in the curriculum outcome area of measurement. Contrary to reveiwed literature, the gaps are more pronounced among low achievers in favour of boys.

The findings also show that 58.4% of boys compared to 54.6% girls received encouraging follow-up moves from their math teachers. The most revealing finding is that entry achievement level is the main source of gender gaps in math learning outcomes, implying that girls start at lower levels than boys and this gap is not closed by school. The policy implication to education of these findings is that while Kenya has achieved gender parity in enrolment, the fact that boys continuously outperform girls implies that boys have better chances of transition to secondary school and tertiary levels than girls, and consequently, broader gender disparities than can be closed by pro-gender education policies may continue to persist.

Keywords

Gender, instruction, opportunity to learn, math, teacher, gain score



1. Introduction

This paper examines gender differentials in mathematics performance in primary schools in Kenya. It uses the scores of a grade six curriculum-based math test and video recorded classroom discourse to investigate gender differentials in opportunity to learn and answer the following two questions: (a) What gender gaps exist in math curriculum areas and cognitive levels the tasks demand; and, (b) Do math instructional practices and classroom interactions contribute to gender gaps in math achievement?

In the first question the analysis focuses on math curriculum outcome areas 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 math while in the classroom, and this contributes to gender gap in math achievement.

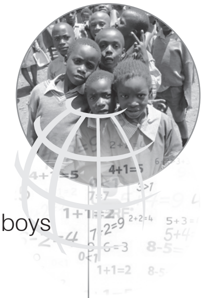
1.1 Gender gaps in math achievement

In the education literature, gender gaps in math achievement has been widely studied, particularly in USA and Europe (see for example. Fennema, Carpenter, Jacobs, Franke & Levi, 1998; Bevan, 2001; VanLeuvan, 2004; Gallagher & Kaufman, 2005; Zhu, 2007; Hyde, 2008; Azar, 2010; Else-Quest, Hyde & Linn, 2010). But this literature is not conclusive and remains both controversial and debatable on whether gender gaps in math achievement really exist and what sources of this difference are. It seems that results vary with context and analytical approach. For example, in USA, Hyde, et al (2008) dismissed the perceived gender gap in math after finding no difference in average performance between girls and boys – based on standardised math assessment involving 7 million students of grade two through eleven.

According to Hyde, et al. the notion that boys do better than girls in math 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 math demanding fields, though she admits that females continue to be under-represented in math, science and engineering-related careers. Other studies in the USA 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 math achievement between boys and girls and continue to conclude that female and male students have nearly equivalent math achievement capacity and levels. Guiso, Monte, Sapienza and Zingales (2008) who, in a cross national study, also found that the gender gap in math performance in favour of boys disapppears or is reversed as cultural-related gender differences diminish. This finding is also supported by Azar (2010), who she argues that if gender difference in math performance exists, they are small and only affect specific areas of math skills at higher levels.

Conversely, there is literature that confirms and supports the existence of gender gaps in math performance. The work of Halai (2010), Ceci and Williams (2010), Plante, Protzko and Aronson (2010), Wiliam (2010), Machin and Pekkarinen (2008), Zhu (2007), 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 standardized tests of math. They continue to argue that such gaps are real and very significant and cannot be trivialised as test scores determine entrant to higher training and by extension 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 U.S. universities, women occupy between 9% and 16% of tenure-track positions in math intensive fields.

In Tanzania, female enrolment in the academic year 2005/06 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 by 1.5 (Benjamin, 2010). After reviewing a large body of relevant literature on gender gaps in math problem solving, Zhu (2007), concludes that literature has consistently reported that boys do better than girls in standardized math test but only among high ability students. This conclusion is consistence with an earlier finding by Bevan (2001) who posits that gender gaps in math attainment are largely concentrated amongst the highest achievers. Fennema, et al. (1998) found no significant different between boys and girls performance in math tasks among early graders (1-3) particularly in number facts, operations and even in non-routine math tasks, a finding that is consistent with that of Wasanga, Ogle



and Wambua (2010) in Kenya. But Fennema's study acknowledged that boys solved more extension problems that required flexibility in thinking.

The debate on gender in Africa is less intense on achievement compared with the literature and debate in the USA. 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 math 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.

Furthermore, Saito asserts that between 2000 and 2007, the directions in gender differences in math achievement were consistent. A further analysis of gender inequalities among the participating countries show that the set of countries where boys outperform girls in math (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 math (Seychelles, Mauritius, Botswana and South Africa) had among the highest GDI of between 0.559 and 0.781 (UNDP, 2005). This is consistence with the finding by Guiso, et al (2008) that used PISA results to show that gender gap in math 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 six math achievements in favour of girls. According to Muthukrishna, the main factors associated with the gender gaps in math included the issue of masculinities, classroom practice and attitudes to learning math. Using grade six SACMEQ II datset for Kenya, Onsomu, Kosimbei and Ngware (2006) found huge (27 points) differences in gender performance in math, in favour of boys. In a study of math performance in different types of secondary schools in Kenya, Bosire (2008) found that streaming based on gender improved math achievement, and particularly for girls. The study recommended institutionalisation of a streaming policy as an intervention for improving girls' performance in math.

1.2 What factors might explain gender gap in math performance?

If gender gap in math achievement does indeed exist, what are the factors that explain it? Zhu (2007) assert that gender differences in math are not solely biologically determined but result from a combination of factors including, psychological and environmental. 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, influence of role model and stereotyping, while on the other hand, psychologist explain the differences using cognitive theory (see for example Azar, 2010; Hyde, 2008; Zhu, 2007; Gallagher & Kaufman, 2005; Bevan 2001). From these studies, four main factors have been mentioned – attitudes, stereotyping, teaching and learning styles, and spatial ability.

Studies have shown that perceptions of mathematics can partly explain gender gaps in math achievement. For example, in USA, APU (1981) found that almost 20% more girls than boys considered themselves lucky if they performed well in a math test. According to Bevan (2001) the main factors that explain pupil's perceptions of math include: expectations; type of activities included in the math curriculum; and the prevailing stereotypes. The effects of stereotype on girls' school performance in math are well captured in 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' math performance is their female teacher's own math anxiety. Plante's study showed girls' math performance decreased as a function of their female teacher's math anxiety; boys math performance remained unaffected. In Pakistan, Halai (2010) found that teachers consider boys to be 'better mathematicians' (p54), arguing that boys are inherently better in math 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.

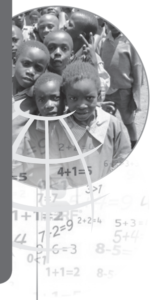
Drawing from developmental psychology, Becker (1995) explores the various ways of knowing in mathematics among females. He concluded that girls are traditionally denied the opportunity to learn math in a way that they would succeed due to the styles of teaching and learning that are not congruent to how

girls approach math tasks. Robin (2001) supports this view when he asserts that girls are ‘connected’ thinkers who require exploration of context and relationship when doing math. This view is also shared by Head (1995) who asserted that on the one hand, girls prefer cooperative, supportive working environment, while on the other hand, their male counterparts opt for competitive and pressurised environment. Traditional models of instructional delivery that encourage disjoined concepts and abstract development of math discipline are therefore inconsistence with what would benefit girls in math learning. According to Hyde’s (1990) meta-analysis of 100 studies, gender gaps in math performance were minimal but gender differences in math problem solving strategies were huge.

The differences in math problem solving strategies were attributed to cognitive abilities, speed of processing information, learning styles and socialisation (see for example Royer & Garofoli, 2005; Zhu, 2007). Gender differences in solving math problems (strategy) 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 strategy while first-grade boys were more likely to use retrieval strategy in solving math problems. Fennema, et al continues to argue that girls are more likely to use concrete strategies while boys will use more abstract strategies.

Related to the strategy use is level of student cognitive abilities. According to Zhu (2007), higher ability students tended to solve problems using more spatial processes, while lower ability students adopt a more analytical way. 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 math 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, debatable and requiring further research. This is particularly so because no single factor can be attributed to gender differences in math 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 difference. It is clear from this literature that gender gap in math is the impact of many different factors that have environmental, psychological and cultural origins. It has also been argued that girls and boys may process same mathematical ideas differently – different strategies of problem solving. Though some studies insist that there are no gender differences, others show that such differences exist. Equitable opportunity to learn math 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 our understanding of how equity in math performance can be achieved, particularly in math domains in geographical regions where little is known. The aim of this paper is to add to this literature based on empirical study undertaken in schools in Kenya.



2. Methods

2.1 Selection of schools and participants

Six districts were selected for inclusion in this 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 4 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 this way, with 12 in each of the six districts. The selection of the schools was random such that it generated the top 20% and bottom 20% in each of the six districts. The KCPE annual league tables is released by district and by school such 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 2,436 grade six pupils were reached, with 1,299 boys (53.3%) and 1,137 girls (46.7%). For this paper, two schools were eliminated because one was boys only school and the other closed down after the first round of data collection and did not offer opportunity for the follow up round 2 data collection. 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 thus had 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).

2.2 Data collection instruments

Three survey instruments and two assessment tools were developed and pretested to improve validity and reliability. The three survey instruments included: a head teacher questionnaire that solicited information on school management, staffing, enrolment, and parental participation in school affairs, among others; a teacher questionnaire that solicited bio-data, qualification and training, discipline, and syllabus coverage; a learner questionnaire that collected information on social economic backgrounds of the grade six learners and their perceptions of the school environment. This questionnaire was administered to each of the grade six pupils in the selected schools. The assessment tools included a grade six mathematics teacher test and a learner mathematics test for grade six pupils. Lesson observations were conducted using a high quality 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 Kenya Ministry of Education, 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), teachers consent was also agreed, and 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.

2.2.1 Video analysis

Video analysis rubric was developed to systematically analyze 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 analyzed using a systematic observation and time-line analysis. The recording was after teachers had consented. According to Ackers and Hardman (2001), this kind of analysis is appropriate because one requires a way of synthesizing 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 in teacher training and pedagogy analyzed 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 analyzed 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 us confidence in the internal analysis of the videos.

2.2.2 Variable descriptions

Gender gap in math achievement: Refers to the observed disparity on standardized math test scores between boys and girls. The gap was also measured by gain score – the difference between scores in rounds one and two of test administration.

Math 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 math curriculum including (Government of Kenya, 2002):

1. Number concepts & 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 (4 test items): In this curriculum outcome, learners are expected to develop a positive attitude towards math and make good use of their time by relating to math skills as demonstrated in making patterns and models, solving puzzles and math games, and relating math to desirable experiences in everyday life.
3. Measurements (5 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 math problems involving various units of measurement, estimate quantities and approximate numbers.

4. Geometry (4 test items): Under this curriculum outcome, students develop special concepts and ability to use them. They categorise objects of different shapes, make geometrical constructions, scale drawing, and applying spatial concepts in everyday life.

5. Basic statistics (3 test items): In basic statistics, students acquire techniques of collecting, representing and interpreting data.

Levels of cognitive demand of math tasks: Stein et al. (2000, p16, 21) classify lower (1 & 2) and higher (3 & 4) levels of cognitive demand of math tasks to include:

1. Memorization (low level) - recollection of facts, formulae, or definitions (12 test items).

2. Procedures without connections (low level) - performing algorithmic type of problems that have no connection to the underlying concept or meaning (5);

3. Procedures with connections (high level) - use of procedures with the purpose of developing deeper levels of understanding concepts or ideas (11); and,

4. 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 learner was mapped on to the curriculum outcome area and/or a level of cognitive demand of a math task for the purposes of analysing gender gaps in performance across curriculum areas and engagement during instruction.

3

3. Results and discussion

3.1 Descriptive analysis

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 test items. In top performing schools, the mean score for boys in test 1 is significantly higher on test items in the curriculum areas of number concepts and measurements and memorization and problem solving levels of 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 performing routine procedures. From these statistics, gender gaps in math achievement is 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 math tasks in spite of their initial score being lower on such items. In the bottom schools, boys had significantly higher gain score on test items related to measurement.

> **From this analysis**
>
> - Boys did better in curriculum area of measurement
> - Boys did better on items that require problem solving/doing math.
> - Girls are good at math task requiring procedures.

From this analysis it was concluded that: (1) Boys did better in curriculum area of measurement and even achieved higher gains over time hence widening achievement gaps in this area. A math test with higher proportion of items on measurement is therefore likely to widen gender gaps in math achievement in favour of boys; (2) Boys did better on items that require problem solving/doing math. Such items require abstract thinking to be resolved; and (3) Girls are good at math task 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.

Our results confirm and support the debate on the existence of gender gaps in math achievement as reported by Halai (2010), Ceci and Williams (2010), Plante, Protzko and Aronson (2010), and Wiliam (2010). However, our findings go a step further to document not only the curriculum areas but also the levels of difficult of math tasks that can exacerbate gender gaps in math achievement. Boys scored more than girls on most items that required a higher level of cognitive demand while girls scored better in items requiring procedures. According to Fennema, et al. (1998), gender gaps in math will not exist if math 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 math achievement.

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

		Mean score, test 1		**Gain score**	
Top schools	**Max score**	**Girls**	**Boys**	**Girls**	**Boys**
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: * Significantly lower*

To have a better understanding on gender differences on improvement of different aspects of pupil's cognitive demands, the results were adjusted for teacher's gender. In the top KCPE performing schools, being taught by a male teacher helps the girls to improve in gain score on test items related to number concept 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 (memorization) when taught by a male teacher. But in bottom schools, boys taught by a male teacher gained more on test items related to number concept, perform complex procedures and problem solving. On gain score, when taught by a male teacher, boys in the bottom schools gained most (3 out of 5) curriculum outcome areas than boys from top schools, and only in one (memorization) level of cognitive demand.

What can be deduced from these statistics is: (1) When girls are taught math 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 math 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 they perform complex procedures and problem solving. In the literature reviewed, we did not find evidence on how the gender gap is influenced by the interaction of teacher's gender and curriculum outcome area.

However, our findings can be explained by gender stereotyping where male teachers are thought to be 'better' math teachers compared to female teachers. This in turn may affect the attitude of girls towards math – as a male dominated field. Teachers can also contribute to poor performance of girls in certain math areas. In Parkistan, Halai (2010) found that teachers consider boys to be inherently better in math; while Plante et al (2010) study showed that female teacher's own math anxiety decreased girls' performance in math, with that of boys remaining unaffected.

Table 2 compares gender gaps in math achievement for pupils in the lowest wealth quitile (WQ1) and highest (WQ5) wealth quintiles. From Table 2, as would be expected, 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 cores, boys from the top schools gained significantly more than girls on measurements, geometry and memorization.

Table 2: Gender differences in math performance within the lowest and highest wealth quintiles

		Mean test 1 score				Gain score			
Top schools		WQ1		WQ5		WQ1		WQ5	
	Max score	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
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*

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, we can confidently argue that clear differences in math achievement emerge after disaggregating data by household wealth quintiles. Disaggregating our data by social backgrounds allows us to compare gender gaps in math within social economic groups. Our analysis shows that gaps still exists even within the same social economic class, an indication that social economic background may not explain existence of gender gaps in math.

Table 3 shows gender gaps in math 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 done using the gain score. For the purposes of understanding gender gaps across academic achievement quintiles, we present data on boys and girls from achievement quintile 1 (lowest achievement quintile, AQ1) and quartile 5 (highest achievement quintile, AQ5). Boys in the top schools and in AQ1 gained more in two curriculum areas and one level of cognitive demand of the test items after controlling for school rank. If we do not control for school rank 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 AQ5, boys gained significantly more than girls in two curriculum outcome areas (pattern & algebra, and measurement) and in one area (memorization) 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 math 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. We can therefore conclude that gender gaps in math 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 standardized math test but only among high ability students; while Bevan (2001) posits that gender gaps in math attainment are largely concentrated amongst the highest attainers, here in Kenya's case we find converse results 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 type II			
		AQ1		AQ5		AQ1		AQ5	
	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*									

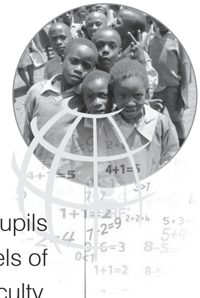


Table 4 presents the levels of cognitive demand of questions asked to pupils in grade 6 during math lessons. The questions were mapped into the 4 levels of cognitive demand of math tasks as a way of assessing their levels of difficulty. Easy questions were placed in the low levels 1 and 2: level 1 was knowing or memorization, and level 2 was questions that required the pupil to perform a routine procedure or conceptualise without connection; difficult questions were placed in the high levels 3 and 4: level 3 was questions that required the pupil to perform a complex procedure or procedures with connections in order to get a solution, while level 4 was problem solving or doing math. In all the questions that were asked, none qualified as a level 4 question.

Out of all the questions asked to pupils during the math 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'. Another 30% and 1% of the questions required the learner to have understood concepts without connections and with connections, respectively. 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 thinking or problem solving skills; (2) Math 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 our data, it would appear that a higher proportion of boys than girls were involved during the lesson.

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.*

Further analysis revealed that 58% of boys and girls in the top schools participated in answering memorization 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 kind of pattern where girls tend to participate more in simpler tasks (procedures without connections – level 2) and less in high level tasks (procedures with connections) could be explained by difference in problem solving strategy between boys and girls reinforced by stereotyping (see Halai, 2010). Literature reviewed suggests gender differences in math problem solving strategies are huge and can be attributed to speed of processing information, learning styles and socialisation (Zhu, 2007; Royer & Garofoli, 2005; Hyde's (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 pupil's gender and follow-up moves/feedback from the teacher. Teachers' feedbacks are categorized 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 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 correct answer, while 11% of boys received very discouraging feedbacks even when the response was correct.

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

All school	Very encouraging		Encouraging		Neutral		Discouraging		Very discouraging	
	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										
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
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										
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
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

Stratifying the results according to school rank gave more interesting findings. For example, there were 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 math 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 hence loose 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 and vice versa is also true. This argument is supported by literature that argues that gender differences in math achievement is 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 (Zhu, 2007).

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 high among the male teachers (49.5%) compared to female teachers (46.8%). Majority of *'discouraging'* (combined with very discouraging) follow-up moves came from female teachers (40%) compared to male teachers (35.6%). A slightly higher proportion (53%) of boys received 'encouraging' feedback compared to girls (51%); whereas girls received high 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 high 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.

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

Teacher's follow-up	Teacher's gender		Pupil's gender			
	Female	Male	Girls	Boys	whole class	Total
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**

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 math tasks during instruction.

3.2 Regression results

Pupils' performance in measurement items show significant differences along gender lines in both top and bottom schools. To identify factors that might explain the observed gender differences in math achievement, we fitted a linear regression model. 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, pre-school exposure, and pupils who reported receiving extra tuition for math at home.

Other covariates include teacher's 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 math test that was administered to teachers in this very study, average age difference between boys and girls, teacher preparedness level, and school rank (top/bottom) in the 4 years of KCPE league table. Table 7 present regression analysis results for all schools, 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 difference in scores on measurement items between boys and girls across all the 3 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 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 & Kaufman, 2005).

Teacher's 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.

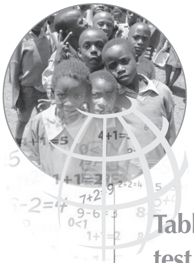
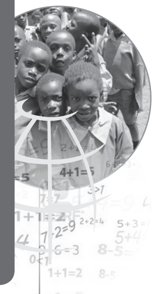


Table 7: Regression analysis results based on performance in measurement test items

	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 teach. 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*

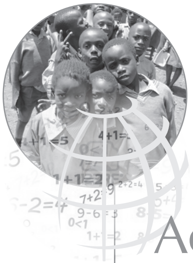


4. Conclusions and implication

Our analysis of primary grade 6 math test score in specific curriculum outcome areas shows existence of gender gaps in mathematics achievement in primary schools in Kenya. The gaps are significantly different in the curriculum area of measurement. We conclude that gender gaps in math are more common among low achieving students in favour of boys. These findings are not consistent with what is known in the literature, whereby, it is argued 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 math in this study. Other factors that create a conducive environment for widening gender gaps in math achievement include teacher follow-up moves.

Therefore, it is concluded based on the evidence and the analysis of the evidence from this study that it is the entry academic behaviour that is the main contributor of gender differences in mathematics 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 math achievement exist in primary schools in Kenya and that they are manifested in different factors which combined lead to the persistence in low math scores for girls.

There are two major implications of these findings that are relevant to the education policy and teaching practice in Kenya: (i) 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 pro-gender development agenda in Kenya; (ii) If teachers become aware of the instructional practices that can lead or widen gender gaps in learning outcomes, then they have an opportunity to put in place mitigating strategies tp minimise inequalities in learning. It may also help in reorganising teacher training practices that recognise the role of the teacher in promoting or closing the gender gap in math achievement in Kenya.



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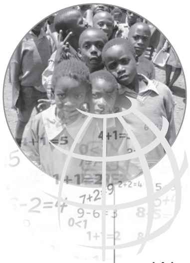

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Appendix 1: A sample of classroom interactions

Qn.	School	Topic	Teachers' question	Teacher's gender	Pupil's gender	Pupil's response	Follow-up move	Encourage-ment level	Sch. Rank
1	1	Measure-ment	What is circumference?	Male	Boy	Distance around a circular object	Correct	Very encouraging	Top school
2	1	Measure-ment	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 re-sponse	Discouraging	Bottom school
7	4	Numbers & frac-tions	What are we supposed to do when converting frac-tions do decimals?	Female	Girl	To multiply	Incorrect	Discouraging	Bottom school

Qn.	School	Topic	Teachers' question	Teacher's gender	Pupil's gender	Pupil's response	Follow-up move	Encourage-ment level	Sch. Rank
8	4	Numbers & frac-tions	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 sup-posed to divide	Incorrect	Discouraging	Bottom school

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