Vol.5 Special Issue No.2 (2022)

Journal of Applied Learning & Teaching

ISSN : 2591-801X

Content Available at : http://journals.sfu.ca/jalt/index.php/jalt/index

Math pedagogical practices in Kenya and Uganda, and their implications to learning in sub-Saharan Africa

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Keywords

Mathematics;
mathematics education;
quality of education;
teaching styles.

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Article Info

Received 5 November 2021
Received in revised form 19 Setember 2022
Accepted 20 October 2022
Available online 25 October 2022

DOI: https://doi.org/10.37074/jalt.2022.5.S2.6

Abstract

This article focuses on the teaching styles and active teaching in East Africa in an attempt to examine what accounts for differences in performance between schools, and provide some lessons for sub-Saharan Africa. It uses data collected from 428 teachers in primary schools in Kenya; and 157 teachers in primary schools in Uganda. Assessment and classroom lesson video recordings of 436 lessons in math are used to generate evidence on patterns of teaching styles and active teaching. Results show that teaching practice in math is inclined towards the command and task styles that do not promote critical thinking among learners. The dominant teaching activity in math lessons was individual seat work in Kenya; and whole class chorus in Uganda. Overall, active teaching accounted for about half of the lesson time, with the other half being used in activities that do not directly enhance learning opportunities. After accounting for country-specific effects and the grade the teacher was teaching, teaching styles did not explain student performance in math, perhaps due to their ineffectiveness. The implications of these findings to the education systems in sub-Saharan Africa countries is the need to reinvigorate teaching practices; furthermore, any efforts to increase daily learning hours will be counterproductive as almost half of the lesson time is inefficiently utilized inside the classroom.

Introduction

Mathematics is a way of life, and it is no wonder that it is taught in all schools all over the world. In our everyday life, mathematics (math) relates to using numbers, measurement, and space to explain a phenomenon of interest. In using math, human beings engage in creative and critical thoughts, logic and looking for solutions.

Given the important role of math in our life, our education systems emphasize the need to build strong foundations in numeracy from early years of schooling and the effectiveness of teaching math. For effective teaching and learning of math[1], two mutually inclusive issues come into mind: (i) pedagogical strategies for teaching math; and (ii) how children learn math. These two are mutually inclusive because the latter is an outcome of the former. In this article, we focus on the former to examine how teachers deliver math instructions inside primary school classrooms in sub-Saharan Africa using data from Kenya and Uganda. The objective of this article is therefore to assess the pedagogical patterns of teaching math, and the extent to which such patterns could be explained by teacher attributes.

Systems of education and attainment levels

While the two countries have different systems of education, they largely mimic each other. Kenya is currently implementing two parallel systems of education, one under the 8-4-4, which was initiated in 1985 and is being phased out, and the competence-based curriculum (CBC) introduced in 2017 (MoE, 2018). The 8-4-4 emphasized progression from primary (8 years) to secondary (4 years) and university (minimum of 4 years) with summative exit examinations at the end of primary and secondary levels. The CBC system has two years of pre-school, six in primary school, and three each in junior and senior secondary schools (MoE, 2018). The structure of Uganda's basic education system which has been in place since independence includes seven years in primary, and four and two years in junior and senior secondary schools, respectively (Kan & Klasen, 2021). While pre-school is not compulsory in Uganda, like in Kenya under the CBC, it is highly encouraged.

The education attainment levels for the two countries differ significantly. For instance, based on SAQMEC IV results, significantly more grade six learners in Kenya (29.5%) had attained at least level 5 (competency) in numeracy compared to 11.2% in Uganda (SACMEQ, 2022). Similar patterns were also evident in literacy, with learners achieving at least interpretive reading (level 5) at 60.6% in Kenya and 31.7% in Uganda (SACMEQ, 2022). The 2021 Uwezo studies showed that only two in five children in Kenya could read grade 3 English text (Uwezo, 2021), while in Uganda only 33% of primary three to seven children could read a primary 2 English text (Uwezo, 2019).

The approach

We use primary data from two close sectional surveys conducted in 2012 and 2015 in Kenya and Uganda respectively. The surveys had teaching styles as part of their focus in an attempt to examine what accounts for differences in performance between schools. This article uses data, collected from 428 teachers in primary schools in urban informal settlements in Kenya, and 157 teachers in primary schools in rural Uganda. Additionally, assessment and classroom lesson video recordings of the 436 math teachers (not all teachers were video recorded), and interviews with subject teachers in the primary schools in the two countries are used to generate evidence on patterns of teaching styles.

The rest of this article is organized as follows: The next section focuses on empirical evidence on math pedagogical practices in Kenya and Uganda. This is followed by a section on discussion that puts the evidence in the context of literature on teaching math, and the strands of math proficiency. In the last section, we provide our own insights and recommendations for policy and practice in the context of education systems in SSA.

Evidence on math pedagogical practices in Kenya and Uganda

In this section, we provide results on math teacher characteristics in Kenya and Uganda, teachers' mastery of math teaching knowledge, the associations between the teaching knowledge and teacher attributes based on multivariate regression, observed math teaching styles in primary school grades 3 and 6, and finally we attempt to map teaching knowledge on math teaching styles.

Math teacher characteristics

Table 1 shows selected characteristics of the math teachers. Overall, 44.4% and 59.2% of the math teachers in Kenya and Uganda were male. When this is stratified by grade, in Kenya, 30% of the grade 6 math teachers were female while in grade three, 81% were female. We observe a similar pattern in Uganda, with 84% and 16% of grade 3 and 6 math teachers being female. In Kenya and Uganda, early primary school grades (e.g. grade 3) are usually allocated to one teacher who teaches all the subjects to students in the allocated class. These statistics imply that in Kenya and Uganda, and perhaps in SSA, early grades are usually allocated to female teachers. In Kenya, while 91.4% of the math teachers had secondary education as their highest academic level, 27% of them had no pre-service teacher training (teacher preparation). On average, teachers in Kenya had about 10 years of experience in teaching mathematics, while in Uganda, on average, had about 9 years. This is an indication of a young teaching force or delayed recruitment into primary school teaching after completion of training or studies.

1 In this article, we use the term math and numeracy interchangeably. However, it should be noted that numeracy has more to do with application of math in real life, and understanding the potential application of math.

Table 1: Math teachers' selected characteristics.

Variable		Kenya	Uganda
		N=428	N=157
Sex	% Female	55.61	40.76
Grade	% Grade 6	50	50.96
Highest academic education	Primary Education	1.17	15.29
	Junior Secondary	0.47	0
	Secondary Education	91.35	84.08
	At least a degree	7.01	0.64
Professional training	Untrained	27.34	5.1
	Certificate	56.31	68.79
	Diploma	10.28	24.84
	Degree	5.61	1.27
	Others	0.46	0
Years as math teacher	Mean (Std. Dev)	7.96 (8.50)	5.16 (5.59)
Average age (years)	Mean (Std. Dev)	32.34 (10.86)	32.51 (8.51)
Average Class Size taught	Grade 3	35.73 (22.67)	61.82 (32.73)
	Grade 6	34.03 (22.87)	55.9 (30.41)
Average years of teaching	Mean (Std. Dev)	9.63 (9.37)	8.81 (6.38)
Average workload (lessons/week)	Mean (Std. Dev)	30.51 (8.41)	23.79 (15.94)

Notes: Junior Secondary is two years of secondary education; while secondary Education is either four or six years; Untrained means no pre-service training.

Teaching knowledge

Among the attributes that define quality teaching is how well teachers exhibit content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) inside the classroom (Carnoy et al., 2008; Georges et al., 2010; Sorto et al., 2009). In this section, we present the results of CK, PK and PCK (in this article, we refer to the three as teaching knowledge) of the math teachers derived from a math knowledge assessment tool (accessible from APHRC on request) administered to grades 3 and 6 teachers in Kenya and Uganda (Ngware et al., 2013; Ngware et al., 2016). We show the performance of teachers in both countries on items meant to measure the three key domains of teaching knowledge considered as essential to effective instruction delivery (Hwang et al., 2018; Shulman, 1986). The three domains are conceptually related though not entirely correlated, with CK encompassing the knowledge of the teacher in the subject matter, PK on how the teacher delivers teaching and strategies used, while PCK referring to the dynamism that guides the teacher to make decisions on delivering learning in diverse classroom situations – i.e. contextualized settings (Loughran et al., 2012; Shulman, 1986).

There is a low correlation between the knowledge domains. That is a correlation of 0.34 between CK and PK, 0.41 between PK and PCK, and 0.44 between CK and PCK. The scores presented in Table 2 can be interpreted out of a possible 100%. Overall, we see a low performance in these key teaching knowledge domains for both countries and grades. In Uganda, while teachers knew the content (high score in CK), delivery and contextualizing it in the classroom seemed to be a problem (low score in PK and/or PCK), while in Kenya, performance in CK, PK and PCK seem not to differ much. The grade 6 math teachers, and male teachers had better performance across the knowledge domains in both countries.

Table 2: Teacher performance (mean scores) on teaching knowledge domains.

		Overall	Grade 3	Grade 6	Female	Male
Kenya	CK	52.14 (1.16)	44.93 (1.68)	59.18 (1.46)	49.29 (1.55)	55.6 (1.72)
	PK	45.29 (0.97)	42.4 (1.35)	48.11 (1.36)	45.22 (1.29)	45.39 (1.46)
	PCK	52.11 (0.83)	46.79 (1.18)	57.31 (1.07)	50.07 (1.14)	54.6 (1.2)
Uganda	CK	51.01 (1.6)	45.13 (2.29)	56.58 (2.07)	44.68 (2.62)	55.27 (1.91)
	PK	29.37 (1.16)	28.15 (1.55)	30.52 (1.7)	28.49 (1.8)	29.95 (1.51)
	PCK	36.62 (1.3)	33.47 (1.88)	39.62 (1.73)	35 (2.02)	37.72 (1.69)

Notes: The test items had multiple responses and teachers were asked to choose/select the best option. For instance, a task would present a procedure for getting the product of 740 and 7. The teacher would be required to select the best option that explains what is happening in the presented procedure. The teacher performance is computed out 100%.

Association between selected teacher characteristics and teaching knowledge

We further explored teacher characteristics associated with the domains by running a multivariate regression. The multivariate regression helps understand the relationship between the three teacher knowledge measures and key variables that can influence the outcome measures. While knowing how well teachers understand the teaching knowledge is important in targeting teacher professional development (TPD) and allocation of teaching tasks, it is equally important to examine patterns and associations between the teaching knowledge and teacher attributes. This will add value to decision-making on teacher in-service training interventions that take context into consideration. To examine such patterns, we use a multivariate regression model. The variables included in the model were teacher gender, academic education level, professional training, grade taught, years as a mathematics teacher, and a score on self-reporting on whether the teacher felt adequately prepared to teach math (Table 3). The coefficient can be interpreted as how much the teacher knowledge measure change for a unit increase in independent variables or characteristic. For instance, how male teachers perform in relation to female teachers. Positive coefficients indicate an increase in performance for a unit increase in the characteristic of interest while negative indicates decreased performance.

In all the knowledge domains, teacher performance was significantly associated with the grade. That is, grade 6 mathematics teachers performed better in the three knowledge measures as compared to those teaching grade 3. The associations among teacher levels of academic education, professional training, and CK are intriguing. Teachers with better education (e.g. completed secondary) and those trained had lower scores in CK and PK than those with primary education or not trained. However, for PCK, trained teachers scored significantly more than those with no teacher professional training - implying that pre-service teacher training adds value. Further, teachers who felt they were adequately prepared (self-reporting or proxy

for confidence) scored significantly higher in both CK and PCK. Also intriguing is the revelation that experienced teachers seemed to demonstrate lower teaching knowledge compared to those with fewer years of teaching - though only significant for PCK.

Table 3: Multivariate regression results.

	Outcome variable					
	CK		PK		PCK	
	Coef		Coef		Coef	
Gender						
Male (*Ref: Female*)	0.18		-2.45		-0.86	
Grade						
6 (Ref: grade 3)	13.08	**	5.68	***	9.01	**
Education						
Secondary (Ref: below secondary)	-8.34	*	2.10		-0.40	
Degree (Ref: below secondary)	-5.12		7.29		3.96	
Professional training						
Certificate (Ref: Untrained)	-0.75		1.76		6.45	**
Diploma/degree (Ref: Untrained)	-2.85		0.36		4.69	**
Country						
Uganda (Ref: Kenya)	-0.54		-14.34	**	-16.16	**
Adequately prepared (Yes)	8.26	*	5.16		5.95	*
Years as subject teacher	-0.06		-0.01		-0.25	**
Constant	46.89		35.25		40.05	

Notes: P-values ** P<0.001; * P<0.05. Scores for CK, PK and PCK are treated as the outcome variable; Coef=Coefficient

Teaching styles inside the classroom

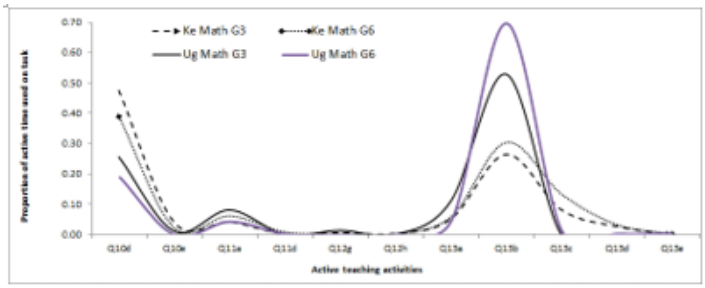
This study analyzed recorded videos and mapped the various teaching activities using a predefined rubric that sought to distinguish between active activities (evidenced student-teacher interactions or student involvement), and inactive activities (little or no interactions or no student involvement). To capture the interactions and/or involvements, the activities were grouped into four main observable categories of individual seat work, whole-class teaching, recitation and group work. More than half of the lesson time was spent on whole-class teaching (teacher speaking and pupil listening), and individual seatwork. The math teachers engaged less in individual and group work. The activities were further grouped into three zones as shown in Figure 1: Zone A as inactive activities that do not directly enhance learning; Zone B and C as activities that promote active teaching but at various levels. The main difference between Zones B and C emanates from student involvement – in Zone B the student asks the questions, while in Zone C the teacher asks the questions. In the two countries, other than in grade 3 in Kenya, about half of the math lessons utilized activities that do not directly enhance learning such as transitioning to an activity.

From Figure 2, whole class activities seem to drive the active teaching zones, with most of the time spent on whole class demonstration (q13b), and whole class instructions (q13a) by the teacher. In addition, a considerable proportion of the time is spent on teachers checking individual work, with

	Zone A	Zone B	Zone C
	Inactive teaching time	Active teaching time	
	Proportion (%) of lesson time		
Ug, math G3	49.37	13.27	37.36
Ug, math G6	47.59	15.12	37.29
Ke, math G3	40.75	6.04	53.21
Ke, math G6	51.52	3.55	44.93
Activities	Activities that do not directly enhance learning opportunities, Eg. Transitioning	Activities: Teacher checking work Individual (stopped); Question and answer – with the student asking; group work with the teacher support; and whole-class teaching, review and lesson evaluation	Activities: Teacher checking individual work; Question and answer with the teacher asking questions; whole class task instruction and demonstration.

Notes: G3/G6=Grades 3/6; Ug=Uganda; Ke=Kenya; We used a timeline analysis rubric to examine recorded videos (classroom observations). This enabled us to capture activities performed by learners and the teacher in the classroom at regular intervals – including teacher-pupil classroom interaction as well as opportunity to learn.

Figure 1: Time spent on active teaching.



*Description of terms/activities used in Figure 2

Q10d	Teacher checking work Individual (working)
Q10e	Teacher checking work Individual (stopped)
Q11a	Q A: Individual learner (Teacher asks)
Q11d	Q A: Individual learner (Learner asks)
Q12g	Teacher checking work group (working)
Q12h	Teacher checking work group (stopped)
Q13a	Whole class task instructions (Teacher only)
Q13b	Whole class demonstrations (Teacher only)
Q13c	Whole class lecture (Teacher only)
Q13d	Whole class review/recap (Teacher only)
Q13e	Whole class evaluate lesson (Teacher only)

Figure 2: Proportion of active teaching time used in each of the active teaching activities.

learners working individually (q10d) and learners asking questions (q11a). We also observe country differences, with teachers in Uganda spending over half of the active teaching time on whole class instruction and demonstration as compared to about 30% in Kenya.

Mapping teaching knowledge to teaching styles

We further related teacher math knowledge with the teaching zones. This was to understand whether teacher knowledge could influence active teaching. To do this, we identified classrooms whose teachers spend at least 50% of the lesson time in a particular zone. The results presented in Table 4 do not show a clear pattern of an association between

time spent on active teaching and teacher knowledge. While in Kenya, grade 6, there is a pattern that is emerging when comparing scores in Zone A (inactive teaching) with Zone BC (active teaching), the differences are not large and conclusive. We are therefore persuaded to believe that there may be little or no association between math teaching knowledge and math teaching styles among math teachers in Kenya and Uganda.

Table 4: Relating active teaching time to teacher scores.

			Teacher mean scores		
Zone	Grade	# of Teachers	CK	PK	PCK
Zone A	UG3	16	47.5	27.8	37.8
	UG6	16	56.9	27.1	39.4
	KE3	38	47.8	42.1	48.4
	KE6	40	54.5	47.8	53.3
Zones B & C	UG3	14	41.4	30.2	37.9
	UG6	24	56.5	33.3	36.9
	KE3	105	41.6	40.1	46.3
	KE6	92	61.6	50.1	60.1

These results highlight the approaches that teachers in Kenya and Uganda employ while teaching math. They also highlight lost opportunities to learn math by learners occasioned by both limited knowledge of the subject and engagement in teaching activities that do not promote learning. These are interrelated, and possibly, the poor use of time in the classroom could be attributed to teachers' teaching knowledge (CK, PK, PCK), which was low.

Discussion

Teacher characteristics: Results from the teacher characteristics show that in East Africa, and perhaps elsewhere in SSA, female teachers dominate lower primary grades. We further see that in Kenya, teachers have slightly longer years of experience (10) compared to teachers in Uganda (9). This implies that we expect some countries in SSA to have teachers who have been in the same position for long (though recent statistics are hard to come by), and perhaps Kenya and Uganda typify such countries, while others may have a less experienced workforce. The retirement age in many African countries for public servants, including teachers, is between 55 and 60 years, and with an average age of about 33 years in Kenya and Uganda, the teaching force can be described as young. Interestingly, data from the Kenya study showed a negative correlation between student math scores and years of teaching experience among teachers in public schools (see Ngware et al., 2013). According to Ngware et al. (2013), for teachers in private schools, as years of teaching experience increased, students' scores in math increased and reached a maximum of about five to six years of teaching experience – there after the students' scores declined. The 2013 study seems to suggest that in private schools, teachers' productivity begins to decline after five or six years in a school. This implies the need for continued professional development to keep productivity high as well as continuous improvement of the teaching environment. Unfortunately, the study did not find a similar pattern in public schools. Of course, we did find that a considerable proportion (e.g. 27% in Kenya) of teachers did not have pre-service training, and this may have contributed to low performance among their students.

Teaching knowledge: In Africa, the majority of primary school teachers are secondary school leavers and/or graduates. In our study, over 84% of teachers in Kenya and Uganda have had secondary education. Additionally, a considerable proportion (over 70%) of teachers have pre-service training. It should therefore be of concern when these math teachers fail to demonstrate mastery of teaching knowledge (they demonstrated low scores in teaching knowledge, that is 39% and 50% in Uganda and Kenya, respectively). Low mastery of teaching knowledge implies suboptimal delivery of contents that could ultimately jeopardize students' progress in math (Mammadova, 2019; Singh et al., 2019; Snoek, 2021). That said, there are variations in teaching knowledge across countries though this (variation) is not translated or associated with student performance. For instance, in Uganda, while teachers had better mastery of the content knowledge, this did not translate to higher scores among their students. The results of the teacher teaching knowledge assessment also confirms that teachers with low 'quality of qualifications' are allocated to the lower grades – for instance, in the two study countries, grade 6 teachers performed better (42% and 55%) than grade 3 teachers (36% and 45%). Interestingly, grade 3 teachers in Kenya outperformed grade 6 teachers in Uganda – an indication of huge variations in teacher quality in SSA. The variations in the demonstration of teaching knowledge implies gaps in quality of instructional delivery that could be a source of inequality in learning opportunities among students. Similar findings have been reported by UNESCO and other researchers in various countries in SSA (Nordstrum, 2015; UNESCO, 2021). Our results also show that female teachers scored less than male teachers did. While there is no evidence to believe that performance is driven by the teachers' gender, it is notable that the majority of teachers in grade 3 are females, and if their performance is low (as shown in this study), this again exposes many grade three learners to less learning opportunities. The presence of more female teachers in lower primary school grades could be explained by two related factors. First is the stereotype that women are good at playing the role of the mother, and especially providing emotional support to young children. Second, it may be the case that female teachers, who also double as mothers, prefer allocations in lower primary, especially grades 1-3, that have fewer demands on their time, hence this provides flexibility to attend to household chores. In some schools, grades 1-3 attend lessons for half a day.

Association between teacher attributes and teaching knowledge: Understanding the association between teacher attributes and teaching knowledge is one way to explore what drives teaching knowledge. In our study, there is evidence to suggest bias in teaching allocations with 'weaker' (in terms of teaching knowledge) teachers allocated to lower grades – these teachers scored significantly lower

than grade 6 teachers. Again, this does not augur well for systems that would likely build strong foundation years at this time of global learning crisis (World Bank, 2019). 'Better' teachers (e.g. with secondary 4 and/or 6 qualifications, or higher teaching knowledge scores), and those with pre-service training demonstrated better mastery of teaching knowledge. By extension, this implies a need for the recruitment of teachers with higher academic and training qualifications. Of course, it was interesting to find that experienced teachers could not demonstrate better teaching knowledge than those who were less experienced – perhaps a demonstration of laxity and/or comfort zone as they get accustomed to their environment. It may also be the case that their entry knowledge was low, and years of teaching experience have not helped to improve it.

Teaching styles: Instructional strategies are critical in improving learning outcomes (Kim, 2015; Rice, 2003; Snoek, 2021). Though it is popular to use and advocate for student-centered pedagogy as it is known to enhance learning (Dong et al., 2019), students at different skill levels in math seem to benefit from different pedagogical styles – this is because they process information differently (Hawk & Shah, 2007). However, our findings show the amount of Zone A activity is very high, and effective teachers may be able to use various teaching styles to cater for the diverse learning needs of their learners. Additionally, the teaching styles are a function of teacher attributes, including the math teaching knowledge. Our study did not find any strong association between teaching knowledge and teaching styles – implying that the deployed teaching strategies are chosen either randomly or conveniently as opposed to being chosen systematically and based on an understanding of the effectiveness of the style. In fact, in Kenya and Uganda, we find no or little association between teaching knowledge and teaching styles among math teachers.

Our analysis made deep dives into the teaching style to unpack those that were active from those that could be described as inactive/passive (see Figures 1 and 2). These activities were grouped under four broad and common (in classrooms) math teaching styles - individual seat work, whole-class teaching, recitation and group work. What we find common among math teachers is the use of whole-class teaching that involved the teacher speaking/telling while students were passive listeners, individual seat work and/or marking/ticking learners' books. These three common teaching activities are not student-centered and hence do not meet the expectations and/or may not be effective in enhancing student performance (Dong et al., 2019; Keiler, 2018). These kinds of styles hardly produce a math-proficiency learner and, in any case, largely disadvantage learners that need either one-on-one, scaffolding, or individualized attention. In fact, 50% of the lesson time was spent on activities that did not directly influence learning (transitioning), such as picking books, wiping the chalkboard, and walking from one point of the classroom to another, among others. While these activities or actions may be necessary, the time spent on them is obviously on the higher side and, by implication, reduces learning opportunities and exposure.

Conclusions and recommendations

In this article, we have shown that female teachers dominate lower primary school grades, and score relatively lower than male teachers in math teaching knowledge assessment. However, this should not be construed to imply that female teachers are not good at math. It may be the case of selection bias – that female teachers who join the teaching profession have low learning outcome scores because of specific affirmative actions adopted by governments. We also find that teachers with more years of experience are not always the best in raising learning outcomes in math.

The current crop of primary school teachers in Kenya and Uganda, and perhaps in many other countries in Africa, struggle with math teaching knowledge. If teachers cannot get it right, then it would be difficult to impart the same and/or facilitate the same to be acquired by their learners. This, if left unaddressed, will continue to create gaps in learning opportunities inside the classroom.

In SSA countries such as Kenya and Uganda, there seems to be an unwritten rule whereby 'weak' (low academic and/or professional qualifications) teachers are assigned to teach in lower primary school grades. If this trend continues, it will exacerbate the learning crisis. There also seems to be an assumption that early grade learners have many opportunities to recover from any learning gaps experienced in their early years. To worsen the situation is the common teaching approaches during math lessons – mainly didactic and hence may not produce an independent learner or a learner who is proficient in math. Perhaps it is these kinds of approaches that make it convenient for math teachers to spend a lot of time in activities that do not directly enhance learning among the students.

Recommendations for sub-Saharan African countries

- There is a need for continued professional development to keep productivity high. While this is happening in some countries, it would be important to make it more targeted in terms of grades the teachers teach, teaching subject areas, math contents, among other teacher attributes that could be related to productivity.

- Foundational years, e.g., early primary school grades, are critical in laying a strong foundation for future success in school. It is therefore imperative that SSA education systems make it a practice to allocate their best teachers to lower grades. This may also contribute to addressing the global learning crisis.

- Additionally, minimum entry qualifications to teacher training and/or teaching should be reviewed upwards. Better-qualified teachers are more likely to grasp the pedagogical concepts, including the knowledge of the teaching subject.

- To change the current and didactic teaching styles inside classrooms, education systems should support teachers inside the classroom with 'how to' teach more effectively. This could be done through school-based coaching activities, among other strategies.

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