Chapter 12
Reform-Based Mathematics in Kenya: A Case Study

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ABSTRACT

The focus of this chapter is to describe efforts to implement reform-based mathematics practices in Kenya preprimary classrooms. As much of the research behind reform-based practices comes from high-income contexts, the authors explore how practices can be adapted to middle income contexts through a case study with seven teachers. Using observations, surveys, and interviews, they present data around two key strategies common in reform-based math: questioning strategies and small group, hands-on work. They show that teachers struggled to use open ended questions, which may be related to their pedagogical knowledge. Teachers were successful with implementing small group work, especially after they were comfortable with the content. They discuss what types of research are needed to better understand how reform-based math practices can be adapted to be used across countries with varying levels of resources.

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INTRODUCTION

The evidence behind reform-based mathematics teaching is vast, and most mathematics education professionals view reform-based mathematics teaching as best practice in classroom instruction (National Council of Teachers of Mathematics, 2014). However, much of the literature on the success of reform-based mathematics come from higher income countries, where teachers receive training in mathematics teaching, classrooms have resources, and class sizes are small. In low- and middle-income countries (LMIC), where primary school teachers are often not trained in mathematics teaching, classrooms frequently have few resources, and class sizes are large, there is instead a body of research on the challenges of implementing reform-based teaching methods and questions around their applicability (Komatsu et al., 2021; Schweisfurth, 2011; Tabulawa, 1997, 2003). These studies show how efforts to implement new practices such as group work, questioning strategies, and active learning have often failed to take hold because of resource constraints as well as cultural and political contexts. Teachers are typically not trained in reform-based math pedagogies, and these pedagogies are often not well adapted to suit the realities of the context.

More research is needed into how elements of reform-based teaching can be adapted to local contexts to increase uptake in LMIC. We define reform-based mathematics as classroom instruction that includes classroom discourse and an emphasis on conceptual understanding that is implemented through activities that connect with and build from students' informal mathematical knowledge. In this chapter, we describe a case study which allowed us to study a real-life phenomenon and test specific theories (Yin, 2017). The case study included classroom observations, teacher interviews, and a teacher knowledge, beliefs, and attitudes survey with seven teachers to examine elements of reform-based mathematics teaching introduced during an intervention in pre-primary classrooms in Kenya. We gathered data in classrooms of 4- to 6-year-old students in government schools located in Uasin Gishu County. We describe how teachers implemented two core elements of the intervention that were based on reform teaching practices: questioning strategies and small-group work. These two elements were integral to the intervention, and teachers were supported through the provision of teachers' guides, training, and ongoing classroom support to implement these elements. Questioning strategies included asking higher-order, open-ended questions that encouraged students to discuss mathematics, explain how they were solving problems, and move away from one-word responses. Small-group work created opportunities for students to construct their own understanding and practice new skills through hands-on practice with materials.

We present data around these two elements, describing what it looked like in classrooms, and pondering how these elements were adapted to the context. Specifically, our research seeks the following answers:

- How were questioning strategies and small-group work taken up by teachers?
- How were teachers' knowledge of mathematical development and their beliefs around teaching pre-primary mathematics related to their classroom practices?

BACKGROUND

Research has shown that children develop a large repertoire of informal mathematical competencies from birth through the pre-primary years, which form the foundation for learning primary school mathematics (Clements & Sarama, 2014; Hungi & Ngware, 2018). Toddlers are able to manipulate the number

of objects, organize them into groups, and change amounts by adding or taking away objects (Baroody et al., 2008; Langer et al., 2003). Many of these informal competencies are developed through play and activities throughout children's everyday lives in daily routines and interactions with family members, friends, and teachers. Effective instruction during the pre-primary years focuses on providing opportunities to further develop these skills, while at the same time exposing children to the more formal mathematics they will encounter in their first year of primary school (Baroody & Wilkins, 1999; Carpenter et al., 1996; Cooke & Bruns, 2018; Ginsburg et al., 1998; Resnick, 1992; Van de Walle et al., 2014). This research on effective instruction has informed many reform-based methods in the United States and other high-income country contexts.

While the majority of the research on mathematics instruction and, in particular, reform-based instruction, has been undertaken in higher-income contexts, there is a growing body of literature on mathematics instruction in LMICs. There is some evidence on the potential positive impact of reform-based methods on learning outcomes in LMICs. Sitabkhan and Platas (2018) reviewed 24 studies of mathematics interventions in LMICs that had resulted in gains in learning outcomes to identify core instructional strategies and found four primary strategies, all in line with reform-based instruction: using multiple representations (Guajardo et al., 2013; Jonason et al., 2014; Näsland-Hadley et al., 2014); knowing and using developmental progressions (Gallego et al., 2017; King et al., 2015; Vaijayanti et al., 2016); supporting student explanation and justification (Education Development Center, 2017; Vula et al., 2017); and integrating formal and informal mathematics (Dillon et al., 2017; McEwan, 1998). Other reports discussing the status of mathematics education in LMICs provide examples of interventions that have shown positive results (Bethell, 2016; Bolton, 2019; Evans & Acquaye, 2019). While many of these efforts incorporated reform-based methods, they also included other inputs and did not systematically measure the impact attributable to the new teaching methods.

A larger body of literature, however, points to the many challenges involved in implementing reform-based instruction in these contexts. Curricula and standards in LMICs may not always reflect developmental progressions and there can be a heavy emphasis on procedural skill rather than conceptual understanding (Evans & Acquaye, 2018; Kusaka, 2019; Pritchett & Beatty, 2012). Textbooks and learning materials are frequently in short supply and children often have to share resources (Read, 2017; Yuan & Evans, 2016). For example, across sub-Saharan Africa, there is on average one mathematics book for every three students (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2016). Access to teaching aids and manipulatives is rare, and when they are available, teachers often have little training or support in their effective use. Mathematics teachers face classrooms that are under-resourced and overcrowded. At the same time, these teachers may struggle with foundational math skills themselves due to their own educational experiences. A cross-national survey of African countries found that, while 90% of teachers could solve basic addition problems, 89% could not interpret data presented in a graph and 85% were unable to solve a word problem (Bold et al., 2017). A World Bank study showed similar problems in Latin America and the Caribbean. For example, 84% of teachers in Peru scored below level 2 as defined by the Ministry of Education, meaning they could not "adapt routine and simple mathematical procedures and strategies" (Metzler & Woessmann, 2012). Similarly, in Paraguay 90% of preschool teachers demonstrated a lack of understanding of the math content they were expected to teach (Inter-American Development Bank, 2015). Given their own struggles with mathematics, the difficult context in which they are teaching, and insufficient ongoing support, many teachers in LMICs will resort to traditional methods they themselves experienced as students: rote memorization and a reliance on procedural drills (Akyeampong, 2017; Hardman et al., 2009; Pryor et al., 2012).

Questioning Strategies and Groupwork

Given the many challenges experienced in math teaching and learning in LMIC contexts, researchers and practitioners have sought to identify entry points for improvement. Given that sweeping changes would likely be difficult to implement and overwhelming to teachers, these efforts have focused on trying to identify instructional strategies that would be contextually appropriate, relatively easy for teachers to begin learning and practicing, and would have impact on student learning, particularly for the development of conceptual understanding. Two key areas that have shown promise in this respect relate to the use of productive questioning and effective use of student grouping.

A core element of reform-based instruction, classroom "math talk" includes rich problems for children to explore and probing questions from the teacher and has been shown to support the development of conceptual understanding as well as procedural fluency (Ball, 1993; Hiebert & Wearne, 1993; Klibanoff et al., 2006; Lampert & Cobb, 2003). Use of productive questions supports the use of explanation and justification, a core focus of many reform efforts. In order to be productive, questions need to support higher order thinking, help teachers to identify student errors or misconceptions, and provide students opportunities to engage in explanation or justification (Lutfeali et al., 2021).

Facilitating small-group work within a math class can be supportive of multiple strategies (Sitabkhan et al., 2019; Lutfeali, et al., 2021). Particularly in the context of large class sizes, such grouping can facilitate explanation and justification, as it will allow more opportunities for children to discuss with each other and engage in math talk. Additionally, when large class sizes are coupled with insufficient resources, teachers can use small groups as a way for all children to engage with manipulatives, which supports understanding and use of representations.

While questioning and use of small groups represent potential entry points for helping teachers to incorporate reform-based methods intro their instructional practice, there remain a number of potential challenges. Teachers who struggle with foundational math concepts themselves, or lack confidence in their own math skills or their instruction, may be hesitant to ask open-ended questions or to facilitate math talk in the classroom that could expose their own knowledge gaps (Akyeampong et al., 2013; Schwille & Dembélé, 2007; UNESCO, 2012). Similarly, groupwork moves some of the control over lesson activities from the teacher to the students. For many teachers in LMIC contexts, this shift may threaten existing norms of teacher authority, as well as present unfamiliar challenges around classroom management (Bethell, 2016).

The Tayari Project

Tayari was a research-based program piloted in Kenya in the four counties of Laikipia, Nairobi, Siaya and Uasin Gishu from 2014-2019. The program was piloted in all public early childhood centers in the four counties. In Nairobi County the program was also piloted in Alternative Provision of Basic Education and Training centers (informal private schools located primarily in poor, peri-urban areas of the capital city). The program was funded by the Children's Investment Fund Foundation with an overarching goal of supporting the Kenyan government to develop a cost-effective and scalable early childhood model to enhance the proportion of pre-primary children (5 to 6-year-olds) transitioning to Class 1 with the requisite school readiness skills and competencies in literacy, numeracy, executive functioning and social-emotional skills.

Results from the Primary Math and Reading (PRIMR) Initiative implemented by RTI International (2011–2014) indicated that well-designed, syllabus-based teachers' guides; intensive teacher training; and targeted ongoing teacher support through coaches improved instruction and led to significant gains in lower primary pupils' literacy and numeracy performance (Piper & Mugenda, 2016; Piper et al., 2016). Building on the strength and success of PRIMR, the Tayari program was designed to test whether a program dependent on the existing Ministry of Education and county structures could also improve early childhood outcomes, as it did in primary grades. Thus, the project worked closely with the National and County governments to develop teacher guides and student books based on the Kenyan Early Childhood syllabus (Kenyan Institute of Curriculum Development, 2017), train and support teachers, and monitor implementation.

Prior to the implementation of the Tayari program, the status quo in most pre-primary classes in Kenya consisted of children sitting in desks with teachers delivering rote instruction, especially in early mathematics. Often, students spent time writing numbers for a large portion of the math instructional time. To improve on this, the Tayari mathematics materials covered a range of competencies including number sense, classification, measurement, geometry and spatial awareness. These activities help students build a strong conceptual base in these domains. Both the teacher's guide and student workbooks included explicit mathematical lessons that were meaningful, engaging, and enabled students to begin to make the necessary connections between informal and formal mathematical concepts.

To achieve changes in instruction, project staff and mathematics education experts, along with experts from the Kenyan Institute of Curriculum Development, created teacher guides and accompanying student books to support teachers to implement small-group work and questioning strategies that promoted mathematical discussions. These materials were based on a spiral approach whereby the program integrated several different topics into one core 45-minute lesson per day. These core lessons were then repeated throughout the year with increasing difficulty each week. The weekly structure was very predictable with Day 1–3 covering number concepts, Day 4 sorting and classifying, and Day 5 measurement. This weekly structure ensured that teachers and students could anticipate topics, making the flow of lessons, materials preparation and management easier. It also meant that students and teachers had multiple opportunities to delve more deeply into topics over time. In this way, the Tayari materials ensured teachers and students saw the connections among topics taught through the daily lessons.

Each lesson consisted of simple activities which were presented clearly and consistently and followed a predictable structure (lesson introduction, main (whole-class) activity, small-group activity, and conclusion). The majority of time in each lesson was dedicated to small-group work where children were actively engaged in a math activity modeled during the whole-group session. Teachers made most of the manipulatives using locally available materials for use during these small-group activity sessions. To support teachers with questioning strategies, "teachable moments" were included in which the teacher prompted the students to think critically around a key concept or skill.

METHODS

Participants

This case study, a detailed look at the implementation of specific practices within a larger study, took place in Uasin Gishu County, Kenya as part of the Tayari project. Participants in our research were seven

teachers and their classrooms in four schools. Class size was between 20-40 in each classroom, which is typical for Uasin Gishu County classrooms. Schools and teachers were chosen by project staff using recommendations from County Early Childhood coordinators (government-employed coaches who provide support to public schools). Coordinators were asked to identify teachers who had consistently been delivering the lessons. We specifically asked coordinators not to identify their star teachers or the teachers that were struggling, but rather the teachers that would be representative of majority of their peers. As part of the Tayari program, all teachers received a 5-day training at the beginning of the first term and a 3-day training at the beginning of the second and third term each year. The training focused on supporting teachers to implement lessons, including structured discussion around how to manage group work and how to ask higher-order questions. Most of the time during the training was spent on teachers practicing lessons with colleagues and receiving feedback.

Instruments

The classroom observation focused on three core areas: instructional practices, use of manipulatives, and small-group or independent work. These three areas were chosen as they represent important elements of reform-based mathematics instruction in both the research literature as well as the design of the Tayari program.

The teacher survey asked teachers to fill in a validated survey measuring preschool teachers' mathematics knowledge and beliefs (Platas, 2014, 2015). The Knowledge of Mathematical Development (KMD) consisted of 20 multiple-choice items that measured respondents' knowledge of early mathematical development. The Mathematical Development Beliefs Survey (MDBS) was designed to measure beliefs concerning (a) age-appropriateness of mathematics instruction, (b) classroom locus of generation of mathematical knowledge (teacher vs child), (c) mathematical development as a primary goal of preschool education, and (d) confidence level in providing mathematics instruction. The MDBS used a six-point Likert scale.

Table 1. Exemplar items from the KMD and MDBS

<table>
<tr><th>Knowledge of Mathematical Development (KMD)</th><th>Mathematical Development Beliefs Survey (MDBS)</th></tr>
<tr><td rowspan="3">☐ Amari is presented with two groups of bottlecaps, one with five bottlecaps and one with two bottlecaps. When asked "How many altogether?" in the two groups, Amari counts all of the bottlecaps beginning with the group of five bottlecaps ("1, 2, 3, 4, 5, 6, 7").
☐ Amari is presented with two groups of bottlecaps, one with five bottlecaps and one with two bottlecaps. When asked "How many altogether?" in the two groups, Amari counts on from the first set ("5, 6, 7").
☐ Same
☐ Do not know</td><td>Math is an important part of the preprimary curriculum.</td></tr>
<tr><td>It is better to wait until Standard 1 for math activities</td></tr>
<tr><td>Mathematical activities are an inappropriate use of time for preprimary learners; because they aren't ready for them.</td></tr>
<tr><td>☐ Rispa answers the following addition question: "If you have these five biscuits and I give you two more, how many biscuits will you have altogether?" (all cookies are present).
☐ Rispa answers the following subtraction question: "If you have these three biscuits and you give me one, how many biscuits will you have left?" (all cookies are present).
☐ Same
☐ Do not know.</td><td>Preprimary learners are capable of learning math.</td></tr>
</table>

The teacher interview asked teachers to reflect on the lesson just taught (see Table 2 for exemplar questions). This semi-structured interview also included questions on the answers the teachers had given on the MDBS and about their perceptions of the four parts of the daily lessons (lesson introduction, main activity, small-group activity, and conclusion). Each interview was approximately 45 minutes long.

Table 2. Exemplar questions from teacher interview

Teacher Interview Questions
Imagine you are talking to a new teacher who is just about to use the Tayari programme for the first time. What advice would you give this new teacher?
Have you created any materials to use during your math lessons that are not provided by the program? Please describe.
Prior to teaching in Tayari project, please describe the materials you used to teach math (i.e. teacher's guide, lesson plans, etc.)

Taken together, these three data sources shed light on how the elements of reform-based mathematics teaching embedded in the program were being manifested in the classroom. This also allowed us to provide a better understanding of the classroom practices of the seven teachers.

Procedures

All seven classrooms were visited one time by the research team. All data collection took place during one week in April 2018. The research team consisted of two international researchers and a Tayari staff member who participated in developing the lessons. In each classroom, we observed one 45-minute math lesson. Each observer took their own notes during the lesson on the observation form, focusing on the three core areas- instructional practices, use of manipulatives, and small-group or independent work. At the end of each observation, the three members of the research team met, compared notes, and created one set of final notes that compiled all the observations into one form. After the observation, one member of the research team asked the teacher to fill out the teacher survey, and then conducted the interview. All notes were written by hand.

RESULTS AND DISCUSSION

In the following section, we interrogate two areas integral to reform mathematics, questioning strategies and active learning through small-group work. We draw on our three data sources to inform our investigation.

Questioning Strategies

Tayari lessons were designed with "teachable moments," which aimed to foster discussions that would promote mathematical thinking. An example is shown in Figure 1. This was done through higher-order questions without one correct answer, such as "How do you know?"

Figure 1. Teachable moments excerpt from Tayari materials

Whole class

- Draw the following table on the board or use number cards.

3	
15	
9	

- Point to the first number (3) and count an equal number of concrete objects with the learners.
- Draw the same number of objects next to the number. Write the number 3 next to the objects you drew, showing learners how to form the number. Guide learners to practise writing the number in the air.
- Repeat the activity for other numbers on the board.
- Ask:
  - ❖ *Which number is greater, 3 or 15? Why?*
  - ❖ *Which number is greater, 3 or 9? Why?*

In the observations, five of the seven lessons did not use the "teachable moments" despite their integration into the lessons. For example, Teacher ID01 was modeling a correct object counting strategy for students by counting five bottle tops. As she did this, she asked the class, "How many do I have?" to which there was a choral response of "five." She then asked a student to come up, and said "Can you confirm that there are five?" The student then mirrored the teacher's actions and counted the five bottle tops. In this way, the questions which the teacher asked were answerable by either one correct response or by repeating a previously-modeled action.

Teachers ID06 and ID07 were the only teachers who asked higher-order questions that did not have one correct answer. Both of these lessons were about buying and selling using money, and the small-group activity asked the students to role play buying items in a market. Teachers ID06 and ID07 were also in the same school, so it is possible that they shared strategies with each other. Teacher ID06, when introducing the play market and modeling it in front of the class, asked "Which coin cannot buy an orange?" After one student answered, she then asked, "Why?" She frequently followed up the questions she asked with "Why?" asking students to justify their answers. Teacher ID07 did not ask "why" questions, but she did ask questions that did not have only one right answer, and could therefore generate more discussion, such as "Can this coin buy a mandazi (Kenyan donut-style pastry)?" and "What do you want to buy?"

While close-ended questions are an essential part of any mathematics lessons, overusing them can lead to children developing a view that mathematics is only about the correct answer. Five of the seven classrooms used only close-ended questions. Questions with one correct answer do not promote the reform-based practices fostered by including the teachable moments in each lesson. However, often teachers do not ask open-ended questions because they may think students are not able to reason about mathematics, or they do not have enough knowledge themselves about the mathematics. To better understand this, we turn to the data from the KMD survey.

The KMD survey measures teachers' content knowledge of children's foundational mathematical development in numeracy. Teachers may miss opportunities to support children's learning if they themselves do not possess an understanding of children's mathematical development (Ginsburg et al., 2014; Pollitt et al., 2020). Most teachers in the study answered lower level KMD items such as whether it was easier for children to start counting from one or six and whether counting past ten was significantly more

difficult than counting up to ten. Teachers ID06 and ID07 responded accurately to additional items that required more knowledge of children's numerical development. Only few teachers were able to answer questions regarding children's foundational development in early arithmetic. For instance, items asking about children's ability to share objects fairly between two or three children and the influence of the size of the set of objects on addition and subtraction problems (a subtraction problem involving three objects is easier than an addition problem involving seven objects) were rarely answered correctly. This data points to the importance of supporting the development of teachers' content and pedagogical knowledge during training.

Group Work

An essential component of reform-based math practices in the early years is hands-on engagement with materials by the students. The Tayari lessons incorporated students' use of materials in small groups. This was done for two reasons: first, most classrooms did not have enough available materials for all students in the class to use them at the same time during independent work. Thus, small groups provided a way for students to share the materials. Second, the small groups encouraged peer learning and collaboration, and students could observe and contribute to the activity. As discussed in the literature review earlier, there is a large body of research both on the importance of group work, and also how difficult it is for many teachers to implement, especially in LMIC.

In particular, pre-primary teachers in Kenya are frequently not used to relinquishing control of what was happening in the classroom. This form of control was mainly observed by teachers wanting to use more whole-class approach and not giving children opportunities to work with others in smaller groups during instruction time. As Teacher ID05 pointed out "*I like teaching whole-group because small groups cause distractions especially if there are not enough materials*." This form of control was also noted with Teacher ID04 who said that she found the whole class easy to teach because "*I'm doing it, I could capture all student attention.*" Teacher ID07 thought that students could not work well with others in their small groups while sharing and role taking, because "*they're still egocentric*." To allow teachers to relinquish control during instruction time, the Tayari lessons integrated reform-based mathematical practices by asking them to put students in small groups and allow them to work independently, providing support as needed. The lessons were structured as a mini-lesson where teachers and students did an activity together in a whole-class setting, and then students in small groups were asked to do that same exact activity with peers. Because this would be difficult, support was provided through classroom coaching and in-service training to enable teachers to successfully support small groups.

In the classroom observations, we found that six of the seven lessons (IDs 01, 04, 06, and 07) utilized small groups. In four out of these six lessons, students had opportunities to use the materials independently during the small-group time, which was the intended purpose of the small-group time. These four teachers were able to relinquish control of the materials and allow students to work with them independently or with peers. For example, Teacher ID01 taught a lesson about number sequencing, displayed in Figure 2. After demonstrating the task of matching number and object cards and then putting them in order, the teacher had students go into their groups. She then passed out a set of number and object cards to each small group. Students in the group each took a few number and object cards, and they talked to each other to match and order the cards. The teacher monitored the progress of the groups, walking around the room and checking each group.

Figure 2. Sequencing activity

Whole class

Demonstrate the following activity:

- Pick a number card and ask the learners to say the number you have picked. Show the learners an object card that matches the number card picked.
- Match the number cards and object cards, as in the photo below.

- Put the number and object cards in order with the learners, from as shown below.

Small group

- Give groups of learners a set of number and object cards from 1–9 for them to match.
- Guide learners to put the cards in order from 1–9.

In contrast, Teachers ID02 and ID03 did not relinquish control to the students during small-group. Teacher ID02 was teaching a lesson where students would pick a number card, count out the appropriate number of bottle tops to match the number card, and then draw the bottle tops in their workbook. After demonstrating this game, the teacher gave each group a set of number cards and bottle tops. She then went to each group to model the activity once more, and then assigned students in a group to do the activity on their own while other students in the group watched. Each group waited until the teacher came around before touching the materials. Because of this, only one student at a time was engaged in the activity, with the rest of the class either watching that student or waiting for the teacher to come to their table. Although this teacher engaged students in small-group work, it was qualitatively different than the structure described above, where all students were actively engaged with materials and working independently.

We now turn to the MDBS survey to understand how teacher knowledge and beliefs played out with regard to group work. We focused on the locus of control, which describes the extent to which teachers believe learning happens through teacher or child agency. Some teachers may believe that they solely are responsible for children's learning and that children play no part in the construction of that knowledge. Other teachers may believe that children alone construct that knowledge. In reality, these beliefs occur on a spectrum between teachers' and children's role in the acquisition of knowledge (Ginsburg et al., 2006, LeFevre et al., 2009). Locus of control is relevant to the observations we made during group work, as we hypothesized that teachers who were more likely to let go of control during group work and allow children to work on their own might have stronger beliefs that children have agency in their own learning.

In examining teachers' beliefs about mathematical development with the MDBS, the seven teachers in the Tayari group included *both* children and teachers as a locus in the generation of mathematical knowledge. Researchers have found that teachers' beliefs around the learning of mathematics relate to their support of mathematical development in the classroom. The teachers we observed agreed with items in the MDBS like "In preschool children construct mathematical knowledge." Group work, a

classroom practice where children actively engage in mathematical concepts outside of the more didactic chalkboard lessons, provide opportunities for children to play a larger role in the construction of their mathematical knowledge.

In addition to completing the MDBS survey, we interviewed teachers on why they marked specific answers on the survey. In terms of locus of control, we asked teachers to explain their answer to this statement: *Pre-primary learners learn mathematics without support from teachers.* All seven teachers disagreed with this statement, with two of them strongly disagreeing. When we asked them to explain, teachers offered justifications in which they emphasized that teachers have to demonstrate how to do something or a particular skill or concept before the student can learn it. Teacher ID02 said "[Students] can't learn without support. Teacher may not give objects, but need to show how/demo first," focusing on how the teacher should first model something before giving it to the student. This aligns with the observation, where the teacher in small groups modeled counting objects over and over at the beginning of the lesson. When one student tried to count seven objects but counted "1, 2, 3, 5," the teacher modeled how to count correctly to seven and asked the student to also count to seven.

We also asked teachers about their perceptions of the different parts of the lesson during the interviews, including small-group work and whole-group instruction. Three out of the seven teachers interviewed felt the whole-group instruction part of the lesson was easiest to teach, while two felt the introduction was the easiest. Most of these sections of the lesson involve the teacher addressing the whole group, which means that five teachers were more comfortable with direct instruction and thought it as the best way to teach math, as opposed to small-group or one-on-one instruction. The whole-group session was also considered an easy activity to teach because it was a demonstration session done by the teacher and during this session, the teacher could capture all students' attention. One teacher shared that she was confident that "*If I demonstrate well during whole-class, children will do it well during the small-group activity.*"

Results such as these shed light on how teachers are using new reform-based practices that were introduced to them in the classroom. While five teachers thought direct instruction was the easiest and best way to teach math, four teachers felt that small-group was easiest for students. Teachers said that small-group activity was the easiest for the students because everyone participates, and students can collaborate, share ideas, enjoy, and learn more. Many teachers reported that they previously had not conducted small groups within their lessons, and that the Tayari lessons pushed them outside of their comfort zone through the daily incorporation of small groups.

Many teachers also referred to the hands-on use of materials during the lessons, and especially during small-group work. When we asked the teachers how their teaching and confidence in teaching math had changed upon joining Tayari, four teachers commented on the increase in the amount of materials they had for teaching. Teacher ID01 acknowledged that no activity within the lesson plan was difficult for them to teach as long as materials are provided because students need them to understand the concepts taught. "*[Math is] not difficult.*" "*With activities, [the] children find it easy. They need to do it. [Teaching] 'take away' [e.g., subtraction] with concrete materials so it's easy for children. Before it was abstract, so [it was] hard for students.*" Teacher ID 6 also added that "*students can use tangible things*" focusing on how her approach to teaching math is now different.

CONCLUSIONS AND NEXT STEPS

This was a small case study, with clear limitations on generalization to teachers beyond the sample. However, the multiple sources of data, taken together, show the struggles and successes of reform-based mathematics teaching practice in new contexts that may have culturally-based ways of teaching and interacting. Even though open-ended questions were provided to teachers, a majority of teachers only asked questions with one correct answer. Asking open-ended questions can be difficult for teachers, especially teachers who are learning a new methodology, because teachers may not understand the student's answer. For example, if a teacher shows the numeral "4" and asks a student, "what number is this?" the answer is known, and if there is an incorrect response, the teacher knows what the correct one is and how to correct that student. However, if a teacher asks a child to explain how they know an answer is correct, or why they think a particular answer is correct, there are multiple ways a child can answer that question, with no clear correct/incorrect judgement to be made.

This situation can be uncomfortable and unfamiliar for teachers in general, and specifically in Kenya where direct instruction has dominated mathematics instruction in the past. Cultural factors come into play as well. A study conducted in Tanzania to understand teacher beliefs behind pedagogical decisions found that embarrassment is a key factor in the classroom (Jukes & Sitabkhan, 2021)—that is, teachers do not want to embarrass students, and teachers do not want to be embarrassed in front of their students. It might be that teachers in Kenya primarily ask questions that they know that students can answer, and that they themselves can respond to appropriately. What can be done to further support teachers and encourage them to ask students more open-ended questions? If further research shows that teachers are worried about embarrassing students, then it could be that adapting questioning strategies to reduce embarrassment but still encouraging mathematical discussion is needed. For example, teachers can begin by asking open-ended questions only for topics they feel equipped to answer, and this can be practiced during a training. Alternatively, teachers can model how to answer these types of questions for students so that students understand what is being asked of them. Finally, students can tell their peers in pairs or small groups how they solved a problem to reduce embarrassment in front of the entire classroom. More research is needed to try these and other methods in the classroom.

From the interviews, teachers indicated that they did not regularly use group work during lessons prior to the Tayari project. We found that teachers in our sample, with support from the project, regularly used group work during math lessons, pointing to the success of the intervention to introduce some reform-based practices to these teachers. We found that teachers mentioned how the materials and activities supported the learning of children, and praised the value of active, hands-on learning, especially when compared with their prior instruction. We also identified challenges. We saw that teachers continued to struggle with letting go of the control of the classroom; it may be that direct instruction is something that teachers are more comfortable with, so asking them to completely turn control of the learning over to students during small-group work may not be feasible initially or may take more time to scaffold teachers into this process. More follow-up studies, where teachers are directly asked about the control of the classroom, as well as studies which aim to understand teacher attitudes and beliefs around how best to teach, are needed to better understand teacher decision-making in the classroom.

One interesting insight from the observations was that, in general, students did not seem to struggle with the content; the majority of questions asked were answered correctly, and most small-group activities were done with ease. Although the content was aligned with the country-level curriculum, it may be that the activities were easy for students. In fact, in subsequent revisions of the materials, the project

has increased the difficulty level of the activities. In some ways, though, it could be that the simplicity of the activities for the first years of implementation provided an entry point into teachers' ability to allow students to work in groups and begin to do activities somewhat independently, as we saw several, but not all, of the teachers do. Although more research is needed, simplicity of content may be one avenue of making teachers comfortable with reform-based practices that they may not be familiar with, where they can be confident that students will not struggle, and they can experiment with different strategies. Then, when content becomes more difficult, teachers will have prior experience to draw on in terms of implementing these elements of reform teaching.

In sum, this study provided insight into classrooms that are just being introduced to reform-based teaching practices in a LMIC. More research is needed across diverse contexts to adapt practices which achieve the same goal as those of reform-based mathematics, such as allowing students to develop rich and nuanced understanding of foundational mathematics skills, while at the same time ensuring that classroom culture is taken into account.

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