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ORIGINAL ARTICLE

Reconciling Teachers' Views and Practices with Early Graders' Ability to Engage in Scientific Inquiry

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ABSTRACT

This study used a three-phase design to explore how teachers' views and practices of scientific inquiry can be reconciled with early graders' ability to engage in scientific inquiry. First, 19 early years teachers were interviewed to explore their views and practices of scientific inquiry. Second, six standard two students were exposed to a problem-solving situation so that their ability to engage in scientific inquiry could be assessed. Finally, six standard two teachers who involved in designing the problem and who also observed students solving the problem were interviewed to explore any changes in their views. The six teachers also participated during the first phase. The findings indicated that teachers had distrust in early graders' ability to engage in scientific inquiry, which corresponded to their rare practice of it. They also perceived large class sizes and unsupportive curriculum as barriers to engaging children in scientific inquiry. Further, the findings indicated that, under specific conditions, early graders are able to engage in some inquiry activities such as framing questions, designing and conducting investigations. Furthermore, changes in teachers' beliefs and understanding of scientific inquiry were noted. Creating supportive curriculum and classroom environments for nurturing children's inquiry are highly recommended.

KEY WORDS: Early childhood; Inquiry; Science; Teachers

INTRODUCTION

Scientific inquiry is increasingly being championed as a pre-eminent approach to teaching science (Cairns and Areepattamannil, 2019; Fitzgerald et al., 2019; Manz et al., 2020; Nadelson et al., 2013; Schramm et al., 2018; Vhurumuku, 2011). Scientific inquiry emphasizes teaching science the same way it is practiced by career scientists (Cairns and Areepattamannil, 2019; Fitzgerald et al., 2019). Indeed, many countries recognize scientific inquiry as a formal approach to teaching science. These includes the United States (National Research Council [NRC], 1996) and South Africa (Dudu and Vhurumuku, 2012b). Such a recognition is well justified, as scientific inquiry has been associated with enhanced self-regulation skills (Crujeiras-Pérez and Jiménez-Aleixandre, 2019; Moote, 2019), self-efficacy in science (Cairns and Areepattamannil, 2019; Fitzgerald et al., 2019), interests and achievement in science (Cairns, 2019; Kang and Keinonen, 2018), well-informed views on the nature of science (Das et al., 2019; Mesci and Schwartz, 2016), promotion of higher-order thinking skills (Moote, 2019), and scientific reasoning (Eshach and Fried, 2005; Fang, 2020; Jensen et al., 2015; Kalinowski and Willoughby, 2019).

With regard to when it should be developed, there is evidence that early graders are capable of engaging in some form of scientific inquiry. Largely, young children have a natural tendency of enjoying thinking about nature; thus, they are capable of understanding science concepts and reason scientifically (Eshach and Fried, 2005; Stone, 2020). Nonetheless, while children in the early grades do not possess cognitive skills required to engage in sophisticated scientific inquiry (Zeineddin and Abd-El-Khalick, 2010), children between the age of eight and ten are capable of dealing with a simplified version of scientific inquiry (Hapgood et al., 2004; Metz, 2011; Schiefer et al., 2019). For example, Hapgood et al. (2004) subjected 21 second grade students from one school in the United Sates to a 10-day program on scientific inquiry and found that the students were able to evaluate scientific investigation procedures, generate evidence from data, and make sense of multiple representations. Likewise, contrary to what is assumed in developmental psychology, the study by Tytler and Peterson (2004) found that, when the complexity of a task was made appropriate, students at the age of 6-8 were able to engage in scientific inquiry.

SCIENTIFIC INQUIRY IN THE CONTEXT OF EARLY EDUCATION IN TANZANIA

The current education system in Tanzania takes the form of 1 year for pre-primary, 7 years for primary (Standard One to Standard Seven), 6 years of secondary education (4 years for ordinary and 2 years for high school levels), and 2, 4, and 5 years of university education. The country's Education and Training Policy (ETP) of 1995 stipulated that each primary school shall have a pre-primary class (United Republic of Tanzania [URT], 1995). Furthermore, the Education and

Training Policy of 2014 pronounced pre-primary education as free and compulsory for every Tanzanian child and reduced its duration from 2 to 1 year (URT, 2014). These policy reforms have had tremendous effects on the early education, turning it into the most challenging one. In particular, introduction of the fee-free policy has resulted to a high rise in enrollments, causing available infrastructures to be overwhelmed. For instance, the National Basic Education Statistics in Tanzania (BEST) which publishes national data on education annually, indicates that there has been a sharp increase in pre-primary enrollments from 1,069,823 students in 2015 to 1562, 770 students in 2016 (Ministry of Education, Science and Technology [MoEST], 2021). To cope with these changes, the country has taken several measures, including recruitment of teachers who did not have the educational qualifications needed to teach in pre-primary and primary schools, establishment of new primary schools (many of which tend to be under-resourced), and increasing enrollment in teacher education programs. Despite these efforts, the effects of the reforms are still felt. For example, in 2021, there were 1193 (14.3%) pre-primary teachers who were unqualified. Further, in 2021, the countrywide student-teacher ratios were 1:98 in pre-primary and 1:63 in primary education (MoEST, 2021). Another effect has been an increase in pupils' dropout cases: for instance, due to a high dropout rates, only 79.1% students complete their primary education cycle in 2021. As well, there has been high rate of teachers' absenteeism. For example, in 2020, 38.2% of pre-primary teachers were absent from their work stations for more than 6 months, mainly due to study leave (63.7%) and maternity leave (24.5%). This is not be surprising since unqualified teachers are supposed to enroll for training and most of the pre-primary teachers in Tanzania are female (76.5% in 2021).

In the present study, "early graders" refer to children at pre-primary (age 5/6), standard one (age 6/7), and standard two (Age 7/8). At these levels of education, children learn science as integrated competences, along with other competences such as numeracy and communication commonly referred as literacy. Moreover, even though scientific inquiry is rarely practiced in science classrooms (Mkimbili et al., 2017; Mkimbili, 2019), teachers and students in pre-and primary schools might engage in various activities that are consistent with scientific inquiry. In support of that, the primary education curriculum in Tanzania (Tanzania Institute of Education [TIE], 2015) recognizes the importance of scientific inquiry. For example, aspects related to scientific inquiry such as conducting scientific investigations, problem solving, and scientific innovativeness are listed as essential goals of primary education (TIE, 2015).

Regrettably, not only is scientific inquiry rarely practiced but also very few studies (e.g. Mkimbili et al., 2017; Author, 2020) have investigated the extent to which students engage in science inquiry in Tanzania.

A recent study by Author (2020) has revealed some barriers to the practice of scientific inquiry, which include large class sizes and unsupportive curriculum environments. Thus, with larger classroom sizes of up to 100 children and curricular overemphasis on literacy and numeracy skills, it is hard to practice scientific inquiry successfully. There is thus a need to investigate how scientific inquiry can be developed among young children in such a context. Yet, no study has attempted to reconcile early graders' ability to engage in scientific inquiry with teachers' views and practices in early education classrooms. This study is an attempt to fill that gap by responding to three questions;

1. What are teachers' views and practices of scientific inquiry in the early grades?
2. To what extent are early graders capable of engaging in scientific inquiry if exposed to problem-solving situations?
3. How have teachers' views changed after participating in planning as well as watching students solve a problem?

SCIENTIFIC INQUIRY IN SCIENCE CLASSROOM SETTINGS

In science education, scientific inquiry is expressed differently by different researchers. For example, it is referred to as "inquiry-based science instruction" (Areepattamannil, 2012, p. 134), "inquiry-based learning" (Moote, 2019, p. 265; Schramm et al., 2018, p. 887), "inquiry-based science teaching" (Fitzgerald et al., 2019, p. 543), "inquiry-teaching" (Jiang and McComas, 2015, p. 554), "science through inquiry" (Dudu and Vhurumuku, 2012b, p. 581), and "classroom inquiry" (Dudu and Vhurumuku, 2012a, p. 150) to mention a few. Despite these variations, emphasis is commonly on teaching and/or learning school science in a manner similar to the way; it is done by practicing scientists (Cairns, 2019; Cairns and Areepattamannil, 2019; Dudu and Vhurumuku, 2012a; Jiang and McComas, 2015; Vhurumuku, 2011). These different terms all indicate school science should reflect the tenets of "scientific inquiry" (Capps et al., 2012, p. 292). However, this principal emphasis of scientific inquiry has been attacked for not providing enough guidance to teachers and students in classroom settings. As a result, efforts have been made to include scientific inquiry into activities that can be implemented in science classrooms. For example, Fitzgerald et al. (2019, p. 544) define scientific inquiry into different levels of inquiry, where open inquiry represents the highest level of inquiry. In open inquiry, students come up with questions, design and carry out investigations, and communicate their results. Guided inquiry is the next level of inquiry in which students are provided with a question and required to design the procedures to test their question and generate explanations. In structured inquiry, students are given a question and procedures for investigation and they are only required to provide supportive evidence. At the other end of this continuum is confirmation inquiry where "students are provided with the question and procedures, and the results are known in advance."

Henceforth, to avoid confusing scientific inquiry with other student-centerd approaches, other researchers have defined scientific inquiry as activities that take place in the classroom.

In this case, scientific inquiry in classrooms entails contexts in which students engage in doing hands-on activities, generating questions, designing investigations, carrying-out investigations, providing alternative explanations, and communicating the obtained results. The present study uses a framework developed by Campbell et al. (2010) (Table 1) to make sense of what scientific inquiry entails in terms of classroom activities.

METHODS

Research Design

This study is based on a constructionism epistemology which assumes that knowledge is socially constructed and dependent on individual's lived experiences (Crotty, 1998). This assumption informed the selection of case study as a research design. A case study focuses on a contextual and in-depth knowledge about a specified real-world phenomenon (Priya, 2020). In this study, teachers and students in the context of an inquiry-based problem-solving scenario were considered as a case for investigation. As teachers and students interact with one another as well as with the curriculum, they form shared meanings that can be investigated qualitatively. Subsequently, interview and observation methods were sought as methods consistent with this type of inquiry (Priya, 2020).

Study Sample

This study was conducted in three phases. The first phase involved a sample of 19 early graders' teachers who were purposefully selected from six schools in North-eastern Tanzania. These were female teachers of pre-primary classes (7), Standard One (6), and Standard Two (6). They were coded as TC-1 to TC-19 to ensure anonymity. Demographically, their age ranged from 30 to 58 years, their working experience ranged between four months and 16 years while their class sizes ranged from 39 to 98 students. These teachers were interviewed to explore their views about the use of scientific inquiry in their own classroom.

Table 1: Tenets of scientific inquiry

Aspect of scientific inquiry	Description
Framing research questions	Focuses on the extent to which students are responsible for framing their own research questions during investigations
Designing investigations	Focuses on the extent to which students are responsible for designing their own procedures for conducting investigation
Conducting investigations	Focuses on the extent to which students are responsible for conducting or carrying out the procedures
Collecting data	Focuses on the extent to which students are responsible for making decisions about data collection during investigations
Drawing conclusion	Focuses on the extent to which students are responsible for drawing conclusions during investigations

Text modified from Campbell et al. (2010, p. 17)

The second phase involved six early graders who were randomly selected from a Standard Two class of one school in North-eastern Tanzania. Standard Two being the highest level of early years education, subjects from this level were assumed to have a comparative advantage in terms of cognitive abilities and knowledge. Six was thought as a manageable number since they had to engage in a collaborative problem-solving situation which permits inquiry skills to me assessed. Their age ranged from 6 to 8 years. For anonymity purposes, those in the pre-primary classes were coded as SS-1, SS-2, SS-3, SS-4, SS-5, and SS-6. These early graders were asked to solve a problem collaboratively to determine the extent to which they can engage in scientific inquiry. The last phase involved six Standard Two teachers who were selected from the pool of 19 teachers described in the first phase. Standard Two teachers were purposefully selected in order to attain a likeness in grade level with Standard Two students who participated in the second phase. Thus, they also participated in planning the problem and also were present when Standard Two students were solving the problem. Since they also participated during the first phase, in-depth interviews were used to explore changes in these teachers' views regarding practicing scientific inquiry.

Data Collection

Semi-structured interviews were used to gain an in-depth understanding of the 19 teachers' views about and practices of scientific inquiry in their classrooms. The face-to-face interview protocol consisted of sample questions such as: What strategies do you use to nurture children's curiosities? How do you help children to frame questions that can be answered through investigation? How often do you engage children in conducting scientific investigation? What challenges do you face when engaging your students in planning and conducting investigations?

The interview protocol was guided by the tenets of scientific inquiry described in Table 1. The interview sessions ranged between 43 and 68 min. For teachers in the third phase, the interviews were used to find out whether or not their views had changed after planning the problem and then watching their students engage in solving that problem.

During the second phase, six early graders solved a problem involving the Archimedes principle as a content domain scenario. Problem-based learning situations encourage students to apply multiple concepts, theories, thinking skills, and ideas in order to solve a problem (Pee, 2019). Further, they provide opportunities for epistemic agency as children engaged in sharing knowledge in a collaborative manner.

The subjects were supplied with two beakers, one full of water and the other half-full. They were also given three sets of wooden and iron bars of the same size but different weights. In addition, rulers and a beam balance were supplied as measuring instruments. The entry prompt required the students to predict what would happen if the bars of varying properties were immersed in the two beakers containing water at different levels. Follow-up questions, prompts, and scaffolds were later used to keep the children focused on the activities related to scientific inquiry as described in Table 1. The whole interaction lasted for 51 min, was video-taped, and later transcribed for further analysis steps.

Data Analysis

To analyze interview data, the researchers read and re-read the interview transcripts so as to be immersed in this data. Scientific inquiry tenets such as framing questions, designing investigation, and drawing a conclusion were used by the researcher to create initial codes, where lexical search was performed to capture relevant phrases such question, practical, experiment, investigat(e/ion), inquir(y/in), and design. Meanwhile, the researchers remained alert to emerging codes that were not pre-determined. Further, to broaden the scope of analysis, line-by-line coding was performed for selected transcript segments. Further, guided by the tenets of scientific inquiry, the researchers watched the video twice using a part-to-whole inductive approach (FitzGerald, 2012). Specific episodes and scenes relevant to the themes of interest were identified and used as the focus while re-watching the video. Furthermore, key defining points in students' decisions that resulted to "aha" moments and breakthroughs were also re-watched.

Both video and interview transcripts were coded by three coders independently to create an agreed codebook. All the coders were experienced researchers in the field of science education. Code agreements of 53.3 and 60.5 for interview and video data, respectively, were reached which later improved to 62.6 and 67.8% after resolving disagreed codes through clarification from each researcher. Furthermore, the 19 teachers who were interviewed were given an opportunity to read the transcripts for cross-checking purposes.

RESULTS

Teachers' Views About and Their Practice of Scientific Inquiry

Framing research questions

This aspect explored teachers' views about early graders' ability to frame research questions that can be answered through investigation. Further, teachers' tendencies to nurture children's curiosity by encouraging them to frame questions to be explored. In general, the majority of the respondents (15/19) believed that children are curious by nature in the sense that they like to inquire about everything around them. They also believed that it is easy for children in the early grades to learn almost everything they are curious about. Nonetheless, the majority of the respondents had no trust in early graders' ability to frame questions that are relevant for scientific investigation. They attributed the inability to do so to the fact that their students are too young to think through complex problems. For instance, TC-13 had the following to say:

> …I don't think they can make questions and identify variables which can be tested through scientific experiments. They [children] will always ask questions that are not relevant to science…like you know questions that are outside the content that you are supposed to teach. This [framing questions] is an issue even secondary school students are still struggling with (TC-13, interview)

With regard to the trust in early graders' abilities to frame questions, no significant variations across grades and teachers' years of experience were found. As the comment by TC-13 depicts, teachers had a perception that children should ask only those questions that are part of the curriculum, instead of asking questions that are outside that eligibility circle as they tend to do. Consequently, and almost consistently across grades and respondents, the results from the interviews indicated that the majority of teachers rarely engage their students in framing questions that can be answered through investigation.

Designing investigations

Regarding the issue of designing investigations, interview results generally suggest that the majority of teachers (13/19) of early graders had less trust in their pupils' ability to design their own procedures for conducting an investigation. Teachers attributed their distrust in the pupils' ability to their (children's) young age, arguing that they are not yet capable of demonstrating complex thinking skills. Further, the findings indicate that all the teachers interviewed do not encourage their students to design investigations on their own. Nonetheless, some teachers (5/19), mostly those teaching in Standard Two (5), had a view that that children should occasionally be allowed to engage in simple science investigations. However, they strongly believed that it is the duty of the teachers to plan the investigations, including all the procedures to be followed. One Standard Two teachers asserted:

> …If a look at them [students in her class], they are all 7 or 8 years old. For the interest of time, I cannot ask them to plan activities for investigation at that age. Don't you think it is the responsibility of the teacher to do so? Have you ever taught young children?...No [the researcher responds] …Okay… for example, when I take them out to observe let say how watered flowers look different from those that were not watered, I already had planned everything myself. I just want them to know the importance of watering plants and not the complex process involved (TC-8)

As TC-8, who has taught for 14 years in the early grades, asserts, there is a hesitation among the teachers to engage early graders in complex thinking skills such as planning investigations. The findings, as TC-8 demonstrated, also suggest that the curriculum of early education provides both opportunities and limits for learning science concepts. For instance, children are supposed to have simple knowledge of the conditions for plant growth. However, planning an investigation around those conditions is beyond early graders' abilities.

Conducting investigation

Conducting investigations is an essential aspect of scientific inquiry and it mainly involves manipulation and testing of variables. The findings generally indicated that the majority of teachers neither believe in early graders' abilities to do so nor do they engage them in carrying their own investigation. However, one teacher a Grade One teacher (TC-17) was an exception as she believed that children are capable of carrying out their own investigation outside school. According to TC-17, "…when they play with things at home children will take this out and replace it with the other." She believed that children engage in manipulation and testing of variables "until they figure out something on their own."

When asked if such activities can happen in schools as well, the majority of the teachers expressed their frustrations with the limits posed by the curriculum.

> …you know as teachers we are guided by the curriculum and priorities expected at this level of education. Every one [teachers] is under pressure to enable the kids master the 3Rs [reading, writing and arithmetic]… (TC-8, interview)

> …I hope you know that I will be evaluated based on children's ability to read, write, and count numbers up to 100. At this level, those [3Rs] are competencies that matters the most and the curriculum is very clear.….and science that they learn required children just to understand simple concepts and life skills such as personal hygiene (TC-4, interview)

Apart from challenges posed by the curriculum, teachers (9/19) said that the large class sizes under their care limit them from engaging children in scientific inquiry. This was expressed by 12 teachers who had class sizes beyond 50, regardless of their working experience. Large class sizes, they said, bar them from conducting investigation as they spend a lot of time helping students to master the 3Rs.

Collecting data (CD)

Under this aspect, the researcher explored teachers' belief about children's ability to make data collection related decisions, including collecting data for answering various questions. As with other aspects of inquiry, the findings suggest that teachers have no trust in young children's ability to engage in such decisions. Furthermore, teachers (16/19) rarely engage their students in collecting data in the context of scientific investigations. Indeed, as in the other aspects, the majority of the teachers (14/19) strongly believed that children are too young to engage in such activities. Instead, all respondents who were interviewed admitted that they engage early graders in bringing in learning materials, mostly materials related to reading and numeracy.

Drawing conclusion

Drawing conclusions entail students' ability to present the results of their investigation by discovering patterns and/or pointing out relationship among variables. The findings suggest that the majority of teachers (13/19) not only believe that children are too young to draw sound conclusions, and also they rarely encourage children to do so. On the contrary, a few teachers (4/19) all teaching in Grade Two believed that children are capable of drawing conclusions if they are given an opportunity to conduct investigations under teacher guidance. However, they too rarely create opportunities for their students to conduct investigations and draw conclusions.

Scientific Inquiry in the Context of Problem Solving

To understand early graders' ability to engage in scientific inquiry, a problem-solving situation was used because it provides an opportunity for a group of students to engage in knowledge sharing sessions without worrying much about getting the right solution. The results from video analysis suggested that the students were interested in interacting with the tools and that they had not engaged in solving similar problem before. Their teachers also confirmed that to have not engaged them in similar activities.

An entry point prompt required the students to predict what would happen if any of the bars are immersed in the two beakers containing water. It was hoped that the prompt would enable early graders to engage in activities consistent with framing questions, designing and conducting investigations, collecting data, as well as drawing some conclusions.

The results indicated that early graders were generally not able to connect their reasoning with any domain of scientific knowledge. At the beginning, they also had flawed reasoning, which changed on the researcher's intervention.

> SS-4 (00:04:19): This [pointing to beaker full of water] there is no space for immersing a bar but in this [pointing to a half full beaker] we can add in these two bars [pointing to wooden bars]
> SS-1, SS-2, SS-5 (00: 04: 28): Yes
> Researcher (00: 04: 30): You did not say anything. You want to say something? [referring to SS-3]
> SS-3 (00:04:39): [Pause for few seconds] Okay, I agree with the others we cannot do anything with a beaker full of water.
> Researcher (00:04:46) But why do you all think a full beaker should be left alone?
> SS-5 (00:04:51): All the water will come out and we can get wet
> SS-6 (00:05: 56): [Laughs] Yes water will come out.
> Researcher (00:04:59): Okay let us focus on the half full beaker. You said two wooded bars can get in here! What will happen if we immerse the two?
> SS-4 (00:05: 11): Mmmhh…I think the bars with sink under water…you know there is enough space here [pointing the bottom side of the beaker] for the bars to stay
> SS-6 (00:05: 19): Let's try, the bar will get wet…yes it will
> SS-3 (00:05: 23): Picks up a ruler, she wants to immerse it into water and see what happen

As the above episode suggests, the students were able to form some reasoning about space. They were also using prior knowledge to form some ideas about what would happen if something were immersed in water; that is, getting wet and floating or sinking. There is also more from the episode. The episode suggests that they had at least figured out that testing their predications could help to clear out their doubts. Indeed, they tested their prediction by immersing the wooden bars in water.

Further, the results suggest during the early problem-solving stages that children were not anywhere close to the researchers' intention, which was to have students say something close to Archimedes principle.

SS-4 (00:08: 07): I will immerse the two bars [wooded bars] and we see what happen. Okay?
SS-5 (00: 08: 14): May be we try to immerse one at a time

They immersed the two wooden bars one at a time. Everyone seemed so interested and eager to learn what would happen.

SS-6 (00:09:11): You were wrong [pointing to SS-4]. See nothing is sinking…the bars are not sinking [laughter]
SS-3 (00:09: 19): May be we add the third bar
Researcher (00: 09: 23): I see! We were wrong before. Seems the bars are not sinking. Who can guess why they are not? Can you try? [Pointing at SS-1)
SS-1 (00:09:31) [Pause for few seconds]: Mhhh. I don't know. Or maybe because they are made of wooden
Researcher (00:09:36): Great! Who has a different opinion?
SS-6 (00:09:41): I think because they made of wooded. Yes, they are not heavy they cannot sink
SS-4 (00:10:01): [Lifts up one iron bar while having one wooden bar on his other hand] Everyone please test, this [pointing to an iron bar] is very heavy compared to this [referring to a wooden bar]

Everyone compared the weights of the wooden bar and the iron bar and confirmed that the iron bar was comparatively heavier than the wooden bar. One teacher (TC-11) suggested that the children should be left uninterrupted for some time to see what happens. The researcher and other teachers agreed that it was a good idea and the students were left to interact with the tools for 17 min uninterrupted. Analysis of the video footages indicated that early graders were very interested in playing with the tools and suggesting several alternatives autonomously. Although their suggestions were not perfectly connected to domain-specific knowledge, they were related with concepts such as weight, space, floatation, and size. Furthermore, whether an object sinks or floats was associated with the object's weight, which may not always be the case. Furthermore, in the 17 min during which the students were left uninterrupted, they were able to formulate questions which they could answer by testing. However, as it can be expected their experiments lacked quality as they could not figure out many important aspects such as how to use a beam balance to measure the weight of the bar and how to use a ruler to determine the changes water height inside the beakers. Instead, they relied on sense making and approximations. They could not do so even in the later stages when they were asked to prove whether the iron bar was heavier than the wooden bar.

SS-4 (00:12:19): Okay. Let's try to immerse the iron bar. It [iron bar] is heavy I think it will sink
SS-5 (00:12: 27): Yes! But we are not sure if it will sink or not. Let's try first.
Looking very nervous and while others watching, SS-4 slowly immerses the iron bar into a beaker half full of water (00:12: 36)
SS-4 (00:12: 38).Yeeehhh! I was right. See [pointing to an iron bar under water]

They continued doing aimless activities such as immersing the ruler in the beaker full of water, and shifting the tools from one place to the other for about 8 min. At this point, they had made a conclusion that heavy objects will always sink in water and vice versa. Nonetheless, nobody had noticed the change in the height of water once the iron bar was immersed in the water as they all focused on the sinking of that iron bar until when SS-5 made a suggestion that resulted to another meaningful discussion.

SS-5 (00:22:01): I was thinking if we add in [into the half full beaker] another iron bar
SS-3 (00: 22:05): Yes, then later we also shall add this [pointing to another iron bar]
[They add the other iron bar and later another one until water start pouring down. They all spend some time wondering]

They could not reason why water was displaced after immersing the three iron bars although at this point they noticed the change in the height of water. Later on, one teacher (TC-7) interrupted by asking "can you try to take out one of the iron bars and see what will happen (00:29:19)? They followed the teacher's advice but then they got surprised to see water pouring out as SS-2 inserted his hand in an attempt to lift up one of the iron bars. They re-filled the beaker several times without providing any concrete explanation for their decision and for the observed changes.

Overall, working as a group enabled the students to engage in activities associated with framing questions, designing and planning investigation as well as drawing conclusions. They also developed interest in manipulating the tools as they tested their own predictions. This implies that early grade students were capable of engaging in scientific inquiry under some conditions.

Change in Teachers' Views About Children's Ability to Engage in Scientific Inquiry

Teachers' participation during the planning stage and during the actual activity of children solving the problem was considered as a means to explore any change in their views about children's ability to engage in scientific inquiry as well as their practice of it. The changes in teachers' view were conceptualized at two stages of participation: the planning stage and the post-problem-solving stage.

The planning stage

The six teachers participated during the designing of the problem where they were involved in key decisions on the kind of tools that should be supplied, the amount of researcher/teacher intervention, and the entry point prompt.

The results indicated that all the six teachers who were interviewed had not engaged in these kinds of activities before, mainly due to their distrust in their students' ability to engage in activities related to scientific inquiry. This was reflected during the first planning meeting in which all the teachers had suggested a more structured form of inquiry so that the children would not "take a road that leads to nowhere" (TC-14). Largely, the teachers believed that students would not be able to think of "anything meaningful" (TC-19) due to their young age. In other words, teachers believed that students would not come up with anything "close to science" (TC-02). However, there was a consensus among all the teachers that the children would find the activity very interesting. Furthermore, the majority of teachers (4/6) had predicted that children would be more active if exposed to hands-on activities. Accordingly, a variation in involvement across grade levels was noted, where Standard Two teachers were more positive about children's ability to engage in the activity as compared to Pre-Primary teachers. On the contrary, there was almost no variation across working experiences. Regarding integrating problem-based learning situations that foster inquiry in their classroom, the teachers perceived barriers to its implementation such as time constraints, class size, as well as unsupportive curriculum.

The post-problem-solving stage

Teachers participated during the problem-solving stage predominantly as observers except in few occasions when two teachers engaged in posing follow-up questions. Post-problem-solving interviews indicated changes in the observing teachers' views regarding two aspects. First, teachers were slowly beginning to believe that early graders can engage in scientific inquiry if they are given an opportunity to do so. In this regard, all the teachers had an improved level of trust in children's ability to engage in scientific inquiry. In particular, they believed that children can design and conduct simple scientific investigations. On the contrary, they belief that children are not capable of framing their own questions and drawing sound conclusions persisted.

Second, the majority of the teachers (5/6) believed that somehow they can navigate curriculum and class size related challenges. Although the curriculum was perceived to be less supportive, the teachers believed that children can be given an opportunity to solve such kinds of problems once in a while. Further, they believed that problems that allow children to engage in inquiry can be integrated in other outdoor activities that are undertaken by children every week. Regarding class size, the teachers believed that they could divide their classes into small groups for the purpose of the activity.

> Watching the students do this activity has helped me to grasp the key aspects of scientific inquiry in practice. I think I can design another activity different from this one (TC-14, interview)
>
> …as they [children] engage in the activity you [a teacher] can easily distinguish investigations from data collection. You can understand how the different aspects which define scientific inquiry play out (TC-02)

Finally, as TC-02 and TC-14 have demonstrated, teachers acknowledged that their understanding of scientific inquiry, both as a concept and as a classroom practice, was enhanced. Accordingly, they believed they can plan activities that engage children in scientific inquiry.

DISCUSSION

The present study has revealed that early grade teachers' have distrust in young children's ability to engage in scientific inquiry. As a consequence, these teachers rarely engage their students in activities that promote inquiry. On one hand, their distrust in children's ability to engage in scientific inquiry can be explained by factors such as large class sizes and unsupportive curriculum environments. On the other hand, the study findings revealed other silent factors that might have influenced teachers' distrust and practices. First, the demographic data indicated that most teachers are assigned to teach in early grades when they in their old age and after they have taught in upper grades for a number of years. Thus, at an average age of 46.7, they constitute a group of teachers who acquired their teacher education in the 1990's or earlier, when the teacher-centered approach to teaching was dominant. In a country where teachers have less opportunities for professional development (Kafyulilo, 2013), these teachers are more likely to hold negative attitudes toward more student-centered approaches such as open inquiry. Second, as the findings suggest, apart from having a negative attitude toward children's ability to engage in scientific inquiry, teachers also exhibited a narrow understanding of scientific inquiry and how to practice it. Thus, to realize the curriculum goal of promoting scientific inquiry, there is an urgent need to instill in these teachers relevant attitudes and equip them with relevant skills through professional development. This follows from the finding that, teachers' understanding of scientific inquiry and their attitudes toward early graders' ability to engage in scientific inquiry changed positively (were enhanced) after engaging in planning and watching their students engage in inquiry. This has implications for teacher preparation programs.

The findings support earlier studies (e.g., Metz, 2011; Schiefer et al., 2019) that found that children age between 6 and 8 years can engage in a simplified version of scientific inquiry. Although their reasoning was not much connected to domain-specific knowledge, the children were able to engage in activities such as framing questions, manipulation of variables, testing hypothesis, collecting data, and making some conclusions.

Further, aimless interaction with the tools was observed. This could be attributed to lack of experience in solving similar problems, as the children had never engaged in such kind of tasks. In this regard, the findings suggest that extended exposure of early graders to guided problem solving in Tanzania could enhance their ability to engage in scientific inquiry and develop other scientific reasoning skills. Indeed, in a context where many schools lack access to resources such as Information and Communication Technologies, using affordable and locally available resources to create problem-solving situations is key to enhancing the scientific literacy of children in marginalized societies. This is important as only 44.9% of pre-primary schools had access to electricity in 2021, with notable variations across regions.

In general, the findings suggest that teachers should guide young children to engage in activities that promote scientific inquiry if they are well guided. However, for teachers to be able to do so, barriers such as large class sizes and unsupportive curriculum and environments will have to be addressed. For instance, although the curriculum advocates development of inquiry skills, it overemphasizes reading, writing and numeracy. Furthermore, the curriculum is highly structured, with strict instructions on what should be taught as well as when and how it should be taught (Author, 2020). As a consequence, teachers are oftentimes under pressure to comply with the curriculum standards and respond to quality assurers who visit schools from time to time. Yet, teacher autonomy in curriculum decisions is very essential in creating an environment for innovative instructional design. As the findings have suggested, problem-solving situations provide a less pressured environment for both teachers and students to engage in activities that promote inquiry. Thus, changing the curriculum philosophy will enhance teachers' autonomy, and consequently, there will be more opportunities to engage their students in innovative activities that promote scientific inquiry.

CONCLUSION

This study explored how Tanzanian teachers' views and practices of scientific inquiry can be reconciled with children's ability to engage in scientific inquiry. The study made four important findings. First, teachers' views about scientific inquiry have tremendous effects on their willingness to engage in it. In particular, their lack of trust in children's ability to engage in inquiry make them not creates opportunities for their students to do scientific investigation. Second, children are capable of engaging in inquiry if they are trusted, given an opportunity, and well guided. Third, participating in children's scientific inquiry can lead to changes in teachers' view about their pupils' ability and enhance their understanding of scientific inquiry. Finally, views about and practices of scientific inquiry are a function of the unique contexts in which it is implemented.

Limitations and Further Research

There is no study without limitations. This one has several limitations. First, due to limited time and resources, the study relied on interviews to explore teachers' practices of scientific inquiry. Observation of teachers' actual practices would have provided the researcher with richer data. Second, only six out of the 19 teachers who participated in the first phase were involved in the third phase. While there were benign intentions to involve a manageable working group, the results in the third phase might have missed important revelations from the other teachers. In general, given the unique context of early graders' education described in this study, there is a need for further studies. For instance, the barriers to engaging students in scientific inquiry such as large class sizes may not be addressed overnight. Thus, there is a need to investigate context-sensitive teacher approaches to engaging their children in scientific inquiry given many confounding pressures placed on the individual Tanzanian teacher. There is also a need to investigate supportive curriculum environment for scientific inquiry that applies in situations such as those found in Tanzania. Finally, the problem situation used seemed somehow to be far too high and beyond the subjects' cognitive abilities and knowledge. Their lack of experience in similar problems adds to this complexity. Nonetheless, the problem provided a relevant situation for assessing students' ability to engage in inquiry activities.

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REFERENCES

Areepattamannil, S. (2012). Effects of inquiry-based science instruction on science achievement and interest in science: Evidence from Qatar. *The Journal of Education Research*, 105(2), 134-146.

Cairns, D. (2019). Investigating the relationship between instructional practices and science achievement in an inquiry-based learning environment. *International Journal of Science Education*, 41(15), 2113-2135.

Cairns, D., & Areepattamannil, S. (2019). Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries. *Research in Science Education*, 49, 1-23.

Campbell, T., Abd-Hamid, N.H., & Chapman, H. (2010). Development of Instruments to assess teacher and student perceptions of inquiry experiences in science classrooms. *Journal of Science Teacher Education*, 21, 13-31.

Capps, D.K., Crawford, B.A., & Constas, M.A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education*, 23(3), 291-318.

Crotty, M. (1998). *The Foundations of Social Research: Meaning and Perspective in the Research Process*. London: SAGE Publications.

Crujeiras-Pérez, B., & Jiménez-Aleixandre, M.P. (2019). Students' progression in monitoring anomalous results obtained in inquiry-based laboratory tasks. *Research in Science Education*, 49, 243-264.

Das, P.M., Faikhamta, C., & Punsuvon, V. (2019). Bhutanese students' views of nature of science: A case study of culturally rich country. *Research in Science Education*, 49, 391-412.

Dudu, W.T., & Vhurumuku, E. (2012a). Exploring South African grade 11 learners' perception of classroom inquiry: Validation of a research instrument. *Science Education International*, 23(2),150-165.

Dudu, W.T., & Vhurumuku, E. (2012b). Teachers' practices of inquiry when teaching investigations: A case study. *Journal of Science Teacher Education*, 23(6), 579-600.

Eshach, H., & Fried, M.N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, 14(3), 315-336.

Fang, S.C. (2020). Towards scientific inquiry in secondary earth science classrooms: Opportunities and realities. *International Journal of Science and Mathematics Education,* 19, 771-792.

FitzGerald, E. (2012). *Analysing Video and Audio Data: Existing Approaches and New Innovations*. In: Surface Learning Workshop, Bristol, UK.

Fitzgerald, M., Danaia L., & McKinnon, D.H. (2019). Barriers inhibiting inquiry-based science teaching and potential solutions: Perceptions of positively inclined early adopters. *Research in Science Education*, 49, 543-566.

Hapgood, S., Magnusson, S.J., & Palincsar, A.S. (2004). Teacher, text, and experience: A case of young children's scientific inquiry. *Journal of the Learning Sciences*, 13(4), 455-505.

Jensen, J.L., Neeley, S., Hatch, J.B., & Piorczynski, T. (2015). Learning scientific reasoning skills may be key to retention in science, technology, engineering, and mathematics. *Journal of College Student Retention: Research, Theory and Practice*, 19(2), 126-144.

Jiang, F., & McComas, W.F. (2015). The effects of inquiry teaching on student science achievement and attitudes: Evidence from propensity score analysis of PISA data. *International Journal of Science Education*, 37(3), 554-576.

Kafyulilo, A.C. (2013). Professional development through teacher collaboration: An approach to enhance teaching and learning in science and mathematics in Tanzania. *Africa Education Review*, 10(4), 671-688.

Kalinowski, S.T., & Willoughby, S. (2019). Development and validation of a scientific (formal) reasoning test for college students. *Journal of Research in Science Teaching*, 10, 671-688.

Kang, J., & Keinonen, T. (2018). The effect of student-cantered approaches on students' interest and achievement in science: Relevant topic-based, open and guided inquiry-based, and discussion-based approaches. *Research in Science Education*, 48, 865-885.

Kinyota, M. (2020). The status of and challenges facing secondary science teaching in Tanzania: A focus on inquiry-based science teaching and the nature of science. *International Journal of Science Education*, 42(13), 2126-2144.

Manz, E., Lehrer, R., & Schauble, L. (2020). Rethinking the classroom science investigation. *Journal of Research in Science Teaching*, 57, 1148-1174.

Mesci, G., & Schwartz, R.S. (2016). Changing preservice science teachers' views of nature of science: Why some conceptions may be more easily altered than others. *Research in Science Education*, 47, 329-351.

Metz, K.E. (2011). Disentangling robust developmental constraints from the instructionally mutable: Young children's epistemic reasoning about a study of their own design. *Journal of the Learning Sciences*, 20(1), 50-110.

Ministry of Education, Science and Technology (MoEST). (2021). *National Basic Education Statistics in Tanzania (BEST).* Dodoma: Government Press.

Mkimbili, S.T. (2019). Meaningful science learning by the use of an additional language: A Tanzanian perspective. *African Journal of Research in Mathematics, Science and Technology Education*, 23, 1-11.

Mkimbili, S.T., Tiplic, D., & Ødegaard, M. (2017). The role played by contextual challenges in practising inquiry-based science teaching in Tanzania secondary schools. *African Journal of Research in Mathematics, Science and Technology Education*, 21, 1-11.

Moote, J. (2019). Investigating the longer-term impact of the CREST inquiry-based learning programme on student self-regulated processes and related motivations: Views of students and teachers. *Research in Science Education*, 49, 265-294.

Nadelson, L.S., Callahan, J., Pyke, P., Hay, A., Dance, M., & Pfiester, J. (2013). Teacher STEM perception and preparation: Inquiry-based stem professional development for elementary teachers. *The Journal of Educational Research*, 106(2): 157-168.

National Research Council (NRC). (1996). *National Science Education Standards: Observe*, *Interact, Change, Learn:* Washington, DC: National Academic Press.

Pee, L.G. (2019). Enhancing the learning effectiveness of ill-structured problem solving with online co-creation. *Studies in Higher Education*, 45, 2341-2355.

Priya, A. (2020). Case study methodology of qualitative research: Key Attributes and Navigating the conundrums in its application. *Sociological Bulletin,* 70(1), 94-110.

Schiefer, J., Golle, J., Tibus, M., & Oschatz, K. (2019), Scientific reasoning in elementary school children: Assessment of the inquiry cycle. *Journal of Advanced Academics*, 30, 1-34.

Schramm, J.W., Jin, H., Keeling, E.G., Johnson, M., & Shin, H.J. (2018). Improved student reasoning about carbon-transforming processes through inquiry-based learning activities derived from an empirically validated learning progression. *Research in Science Education,* 48, 887-911.

Stone, B. (2020). Understanding the influence of teacher-directed scientific inquiry on students' primal inquiries in two American science classrooms. *Journal of Research in Childhood Education*, 34, 521-537

Tanzania Institute of Education [TIE]. (2015). *Primary School Syllabus for Standard I-VII.* Dar es Salaam: Ministry of Education, Science and Technology.

Tytler, R., & Peterson, S. (2004). From "try it and see" to strategic exploration: Characterizing young children's scientific reasoning. *Journal of Research in Science Teaching*, 41(1), 94-118.

United Republic of Tanzania [URT]. (1995). *Education and Training Policy*. Dar es Salaam: Government Press.

United Republic of Tanzania [URT]. (2014). *Education and Training Policy*. Dar es Salaam: Government Press.

Vhurumuku, E. (2011). High school chemistry students' scientific epistemologies and perceptions of laboratory inquiry. *Chemistry Education, Research and Practice*, 12: 47-56.

Zeineddin, A., & Abd-El-Khalick, F. (2010). Scientific reasoning and epistemological commitments: Coordination of theory and evidence among college science students. *Journal of Research in Science Teaching*, 47(9), 1064-1093.