An investigation of teacher's practices when teaching mass measurement in grade 4 in Malawi

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This paper reports on a study on teachers' practices when teaching mass measurement in grade 4 in Malawi. Data was collected from video recordings of three grade 4 teachers (two lessons each) who were purposively sampled to ensure they were teaching measurement of mass. The teachers' practices were analysed using the Mathematics Discourse in Instruction (MDI) framework. Findings of the study showed that the common teachers' practices included: having lesson plans with clear lesson goals, using similar examples and tasks throughout the lessons, involving learners in hands-on activities without providing the conceptual understanding of the tasks, and asking low level questions. We argue that teachers' practices when teaching mass measurement should focus more on developing learners' conceptual understandings of mass measurement.

Keywords: Teacher's practices, mathematics discourse in instruction, measurement, mass.

Introduction

Measurement of length, area and mass is a central part of primary school curriculum in many countries (e.g., Ministry of Education, Science and Technology [MoEST], 2006; National Council of Teachers of Mathematics [NCTM], 2020). Research on the teaching of measurement shows it is poorly taught in many countries and is focused on procedures rather than conceptual understanding (Clements, 2003, Irwin et al., 2004, Zacharos, 2006). Stephan and Clements (2003) have attributed this to curricular content, teachers' knowledge and instructional practices. Cheeseman et al. (2011) challenged the traditional-curriculum approach of using informal units for an extended period of time before introducing standard units of measure, and Zacharos (2006) showed that both students and teachers have difficulties in understanding the concepts of measurement.

While several studies have investigated the teaching of length and area measures, less is known about the teaching of mass measurement in primary school. For example, in our review of research reported in CERME11 (see Jankvist et al., 2019), we found 12 studies reporting on the measurements of length and area, but none reporting on the teaching of mass measurement. In addition, research about the teaching of mass measurement in the Malawi context is specifically lacking. This motivated us to investigate Malawi teachers' practices in the teaching of mass measurement. Measurement is one of the core elements of the mathematics curriculum in Malawi, from grade 1 through secondary school. For grades 1 and 2, the curriculum includes mass measurement using non-standard units, while in grades 3 and 4, learners are introduced to the standard units of mass and are taught how to measure mass in kilograms and grams (MoEST, 2006). The learning of measurement involves the use and understanding of procedures and the development of conceptual understandings. In the literature, these are commonly discussed in relation to length measurement (e.g., Battista, 2006; Lehrer et al., 2003) but can be transferred to other measurement concepts like mass.

According to Cheeseman et al. (2011) children need rich experiences involving the measurement of mass, especially in the early grades. Rich experiences are those in which learners are offered opportunities to engage in activities that lead to conceptual understanding in mathematics and challenge them to think and foster the communication of mathematical reasoning.

We describe teacher practices as what teachers do and say in a lesson. Teacher practices matter in mathematics lessons and determine what learners learn and the skills they acquire (Adler, 2017). This is particularly critical in teaching measurement and in early grades where learners depend on teachers to learn. The need to understand practice in the Malawian context motivated our research question:

What are teachers' practices when teaching measurement of mass in grade 4 in Malawi?

Literature review

McDonough et al. (2012) found that although measurement may look simple, insights gained from research into young children's concepts of mass measurement show that the learning of measurement can be complex. Some studies on mass have focused on learning in early grades. McDonough (2010) showed that children in the early years of school have informal knowledge of mass measurement. They develop this knowledge during outdoor play activities prior to formal schooling. Some acquire the knowledge of mass measurement from handling or weighing things at home (Spinillo & Batista, 2009). Cheeseman and McDonough (2013) reported that children's learning about measurement continues from experiences prior to school through formal schooling, where they are taught about attributes of measure including length, mass, time, area, angle, and volume. MacDonald (2010) found that children four to six years old have an awareness of the attribute of mass, as revealed in drawings of measurement situations. These and other findings reveal the importance of underlying knowledge and skills that early grade learners bring to the learning of mass measurement. These include informal knowledge of mass, handling or weighing objects and attributes of mass. Knowing learners' prior knowledge ensures that the teacher works towards building on what is already known and correcting misconceptions.

The teaching of mass in early grades involves measuring in both standard units and non-standard units. McDonough and Cheeseman (2015) found that in learning to measure, children develop other skills, such as how to use a balance scale, and develop understanding of foundational ideas, including awareness of the attribute, comparison and unit iteration. Other skills that learners develop in measuring mass are precision and origin (Lehrer et al., 2003, Sarama & Clements, 2009). Therefore, in teaching measuring mass in standard units, more skills and knowledge are developed in learners. These skills are used or applied in other mathematics topics and subjects like science.

Other researchers have pointed out the need for learners' conceptual understanding and reasoning when they are measuring in standard units. Wilson and Osborne (1992) found out that while the basic idea of direct measurement is simple, there are complex mental accomplishments within measuring that are often downplayed in typical lessons. Opportunities for children to reason, with the purpose of coming to understand foundational or key ideas of measurement, can be enhanced by task design and teacher actions when carrying out those tasks. This makes the teaching practice important as what teachers say and how they say it matters for children's learning (Adler, 2017).

Theoretical framework

This study used the Mathematics Discourse in Instruction (MDI) as its theoretical and analytical framework. The framework was developed from extensive research among poorly resourced schools in South Africa (Adler & Ronda, 2015). The MDI framework describes the lesson "bit by bit" meaning step by step, thereby analysing teaching shifts that take place in a mathematics lesson. This way of analysing the lesson was useful in this study as it enabled thorough understanding of the shifts in teaching practices and how each shift made mathematics available to learners.

In describing the framework, Adler and Ronda (2015) represents it diagrammatically as below:

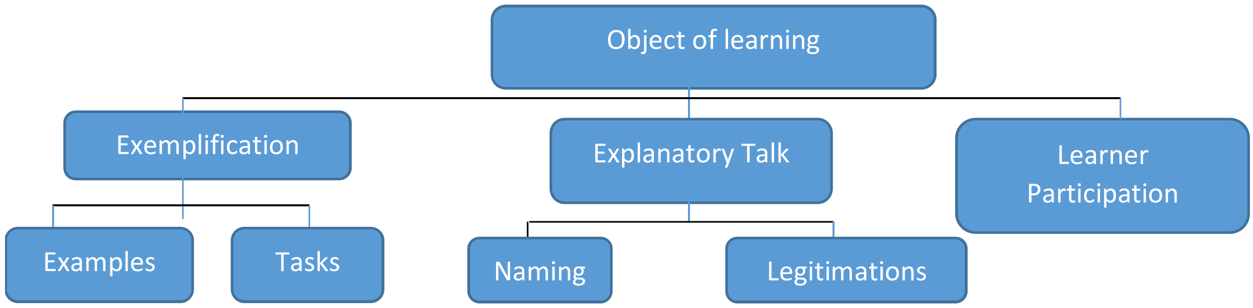

Figure 1: Constitutive elements of MDI (Adler & Ronda, 2015, p. 3)

The four constitutive elements of MDI are object of learning, exemplification, explanatory talk and learner participation. Object of learning is regarded as the lesson goal (that which students are to know and be able to do). In the diagrammatic representation above, Adler and Ronda (2015) separate the object of learning from the other components of MDI. The three components of *exemplification*, *explanatory* talk and *learner participation* are viewed as the key mediational means or cultural tools in a typical mathematics classroom instruction. These tools are used to achieve the object of learning. Exemplification which is further divided into *examples* and *tasks* is a common practice in mathematics teaching where lessons start with examples followed by similar tasks for learners' practice. Examples are categorized into three levels, from Level 1 to Level 3, depending on whether the selection of examples are similar, contrasting, or a combination of the two.

Explanatory talk involves communication by the teacher that takes place during the lesson. It is divided into *naming* (words used to name the mathematics being discussed) and *legitimation* (explanations of what is to be known and done in the lesson). Naming is also categorized into three levels: Level 1 meaning colloquial language is used, including ambiguous referents such as this, that thing, to refer to objects; Level 2 if some math language is used to name the object or component, or the string of symbols is simply read when explaining; and Level 3 if appropriate names of math objects and procedures are used. If non-math legitimation is used (such as visual cues, or metaphors relating to features), it is classified as Level 1 NM (nonmathematical); Level 2M (math) if a specific/single case, real-life application or purely mathematical explanation are used; Level 3M (math) if equivalent representations, definitions, or previously established generalizations are used but explanations are unclear or incomplete; and finally, Level 4M if it is a general full explanation.

Learner participation on the other hand allows learners to participate in the teacher's communication even if it may be in form of mostly listening to the teacher (Adler, 2017). It also involves their participation in answering questions. It is also categorized in three levels: Level 1 if learners simply answer yes/no questions or offer single words to teachers in the form of unfinished sentences; Level 2 if learners answer (what/how) questions in phrases/sentences; and Level 3 if learners answer why questions or present ideas in discussion, or the teacher revoices/confirms learners' questions.

Methodology

This study collected qualitative data from three teachers in three classrooms in two schools in Malawi. The teachers were purposively sampled to ensure that they were teaching mass during the time of data collection. Two lessons from each teacher were observed and video recorded. We used the MDI framework to analyse what the teachers were doing and saying in class to make the idea of mass available to learners. We sought consent from the District Education Office, Head teachers and teachers themselves to record the lessons. Teachers were free to withdrawal from the study anytime within the data collection exercise.

Findings of the study

Due to limited space, in this section we present one sample lesson in detail and its analysis using the MDI analytic framework. The title of this illustrated lesson was "Kulemera kwa Zinthu" meaning mass of objects. The teacher guide gave the following success criteria of the lesson: i) measure mass in kilograms (kg) and ii) measure mass in grams (g).

Following the MDI framework, the lesson was divided into five events, with a new event distinguished by a shift in activity. Below is a detailed description of the events with dialogue between the teacher and the learners.

Event 1: Measuring using non-standard units

The teacher carried a stone and a duster in her hands and asked learners to identify which one of the two was heavier than the other. The learners were able to identify the stone as being heavier than the duster. The activity was repeated using two stones of different sizes. The learners were able to identify the heavier stone, judging from the sizes of the stones.

Teacher	Which stone is heavier between Stone A and B?
Learners	Stone A.

Event 2: Measuring using unmarked simple balance

Learners were shown a simple balance and the teacher explained how it is used to determine which object has more mass than the other or if any two objects have the same mass.

Teacher	The balance tilts on the side where there is a heavier mass. That shows that one object is heavier than the other. When the two objects have the same mass, the balance does not tilt.

The teacher demonstrated how to measure two stones by putting them in bags and hanging the bags on the simple balance. The learners were able to identify the stone with a bigger mass. This activity was repeated using different objects such as duster, stones, books and pencils. Learners carried out the rest of the activities in pairs.

Event 3: Comparing masses of objects with a 1 kg packet of sugar

In this activity learners were comparing mass of an object with a 1 kg packet of sugar on a simple balance. The teacher put a stone in one bag and a packet of sugar in another bag and hung the bags on a simple balance. Learners were able to identify which one of the two had more mass than the other by looking at how the simple balance tilted. The learners repeated this activity using stones of different sizes and a chalkboard duster.

Teacher	Which is heavier between a 1 kg packet of sugar and a stone?
Learners	A packet of sugar.

Event 4: Introducing gram (g)

In this event, the class continued to compare the mass of 1 kg of sugar with various objects using a simple balance. The teacher was careful to choose objects that were less than 1 kg this time around. The learners were then informed that objects that were less than 1 kg are measured in grams. The learners identified items such as 500 g salt and 100 g baking soda that were present in class. The class was comparing masses of items in grams with the 1 kg packet of sugar using the simple balance. Similarly, the teacher put the 2 masses under comparison in bags and hung them on a simple balance.

Teacher	Which is heavier between a 1 kg packet of sugar and a 500 g packet of salt?
Learners	1 kg packet of sugar.

Event 5: The relationship between kg and g

The last event was for learners to establish the relationship between kg and g. The teacher showed that 500 g + 500 g = 1 kg by comparing two packets of 500 g salt and 1 kg packet of sugar on a simple balance. Learners identified the two sides of the simple balance as the same and concluded that 1000 g = 1 kg. The learners were later given the following three exercises to write individually in their exercise books: i) 250 g + 250 g + 500 g = ____ kg, ii) 3 kg = ___ g, and iii) 200 g + 500 g + 300 g = _____ kg.

Discussion

There were two lesson goals given by the teacher: i) measure mass in kilograms, and ii) measure mass in grams. These identified objects of learning were well captured in the lesson plan. Most of what happened in this class was direct comparison of masses of objects using standard and non-standard units. The common question by the teacher in the first four events was: Which is heavier between a stone and a packet of sugar? At this point, learners' judgement of "heavier than" was based on how the simple balance tilted. In event 5, learners were comparing known masses of items such as 1 kg of sugar and 500 g of salt.

The lesson intended to teach learners how to measure masses in kg and g. However, what happened in this class was mostly comparing and ordering masses of objects. According to Cheeseman et al. (2011), comparing, ordering and matching masses of various objects are important skills in mass measurement. They form part of the preliminary skills that children should acquire in measurement. However, more skills and knowledge of mass measurement need to be acquired in the early years of primary schooling.

The second element of MDI is exemplification and it consists of examples and tasks. Mathematical goals are supposed to be achieved through elaborated examples and given tasks. Since the lesson under discussion was mainly hands-on, we analysed the hands-on examples and tasks that the learners were given and the materials with which the children were engaged. However, when analysing the five events of the lesson, it was observed that the tasks were similar in terms of level of difficulty and demands for cognitive ability. The instructions for the tasks were the same and repetitive. Further, the tasks were set procedures in comparing the given masses. The lesson focused on teacher's instructions on how to compare different masses of objects. Conceptual understanding of the underlying idea of mass and measuring mass in standard units of kg and g was missing in the lesson.

The third element of MDI is explanatory talk. The MDI framework divides teacher explanatory talk into naming and legitimations. In this case, naming are mathematical terms used in the lesson while legitimations are explanations of mathematical ideas and procedures. The two are divided into three levels (low to high) depending on the teacher's use of mathematical language in the lesson. In terms of naming, we observed that the teacher mostly operated at Level 2 and 3 where she was able to use appropriate mathematical language to name objects, simple balance, 1 kg, 500 g masses, and measuring mass in kg and g among others.

In terms of legitimations, we observed that teacher talk was generally of Level 1 and 2. The teacher was giving explanations that were simple, single and isolated cases with real life examples. For example, she explained with the help of a simple balance that the mass of two 500 g salt packets is equal to 1 kg of sugar. The teacher's explanations were characterised by the use of unspecialised mathematics to name mathematical terms and compare masses of objects. In line with Adler (2017) reporting that what teachers say and how they say it matters in mathematics lessons, especially in early grades where learners depend more on teachers, we observed that the selection of tools of measuring mass affected the teaching and learning of the lesson.

The fourth element of MDI is learner participation. Learners participated in carrying out activities in measuring masses of various objects and in answering questions from the teacher. The MDI framework describes learner participation in terms of levels of answers provided by learners. It was observed that learners' answers were of both Level 1 (the yes/ no answers) and Level 2 (what, which and how answers). For example, the common question in this lesson was: Which is heavier between stone A and stone B?

Conclusion

This study collected and analysed qualitative data to find out teachers' practices in grade 4 when teaching mass measurement. Using the MDI framework, we divided the lesson into five events, in which each event was characterised by a shift in the activity. We analysed the three cultural tools of a typical mathematics lesson according to MDI; exemplification, explanatory talk and learner participation based on their level of complexity. The object of learning was also analysed to find out if the intended goal of the lesson was achieved.

While we only presented detailed data from one lesson, the study established that all the teachers had lesson plans with clearly stated lesson goals (success criteria); to measure mass of objects in kg and g. However, it was not clear whether learners achieved this intended lesson goal. In terms of examples and tasks, teachers used similar examples in different events of the lesson such that the examples looked like a repetition of what had already been done. The examples were teacher demonstrations of measuring in grams and kilograms. Most of what was called measuring in g and kg activities were direct comparisons of objects of known masses. Teachers' explanations followed the examples and tasks that they did in class with learners. These were mostly instructions on how to compare objects using simple balances.

Possible implications from using these identified practices in the teaching of measuring mass in grade 4 in Malawi is that some learners may not be able to measure mass of objects in kg and g by the time they finish grade 4 because the teaching of mass did not prepare them adequately with the measuring knowledge and skills. We also noticed that teaching is compromised by the lack of resources such as scale balances to use during the teaching of measuring mass. A final observation is that teachers' practices are determined by suggestions from the curriculum material. Therefore, improving curriculum materials would provide better guidance to teachers so they can better support learners to develop conceptual understanding of mass measurement.

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