YOUNG LEARNERS' UNDERSTANDINGS ABOUT MASS MEASUREMENT: INSIGHTS FROM AN OPEN-ENDED TASK

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In response to an open-ended assessment task, 282 children of 6 to 8 years of age revealed their understandings of mass measurement. Each of the Year 1 and 2 children in 13 classes from 3 schools represented their knowledge of mass measurement in drawing and / or writing. Responses ranged from portrayals of activities they had undertaken or materials they had used in classes, to the more explicit articulation of key mathematical ideas. This paper presents samples of children's responses that illustrate a range of thinking and conceptual development about mass measurement revealed by the assessment tool.

INTRODUCTION

Although measurement is an important element of mathematics education, there is insufficient research in this area (Sarama, Clements, Barrett, Van Dine, & McDonel, 2011; Smith, van den Heuvel-Panhuizen, & Teppo, 2011). Smith et al. wrote of poor learning of measurement around the globe and called for the development of assessments that are more revealing of children's learning. In recent work, we have attempted to address some of the concerns related to both the teaching and learning of mass measurement (Cheeseman, McDonough, & Ferguson, in press). In a design experiment (Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003) we implemented rich learning experiences in mass measurement (McDonough, Cheeseman, & Ferguson, 2013) and evaluated children's understandings through use of a one-to-one interview (Cheeseman et al., in press). Our research has included assessment through the development and use of a pencil and paper test (Cheeseman & McDonough, 2013), and the administration of an open-ended task. Findings from administration of the latter are the subject of this paper. Our main purpose here is to present insights into the range and complexity of young children's reflections on their thinking about mass measurement.

In line with the philosophy of social constructivism, we hold "respect for each individual's … sense-making … [and children] … are seen as active and enquiring makers of meaning and knowledge" (Ernest, 1991, p. 198). Interpreting children's thinking from this perspective, we are interested not only in the common features in understandings as communicated by responses to the assessment task, but also in the differently constructed understandings that reflect the range and complexity of thinking exhibited by young learners when measuring mass.

We use the term mass rather than weight as it is the term used in the Australian Mathematics Curriculum (Australian Curriculum Assessment and Reporting Authority (ACARA), 2012). We recognize that among researchers and educators there are

2014. In Liljedahl, P., Oesterle, S., Nicol, C., & Allan, D. (Eds.) Proceedings of the Joint Meeting of PME 38 and PME-NA 36,Vol. 4, pp. 193-200. Vancouver, Canada: PME.

different interpretations of these terms and note that the English language adds complexity as we have no verb for the noun and we "weigh" objects to ascertain their mass. In our reading of research we found use of both terms mass and weight.

BACKGROUND

Young children are known to possess knowledge of mathematics, often informal knowledge, that is "surprisingly broad, complex, and sophisticated" (Clements & Sarama, 2007, p. 462) but research provides limited insights into young children's understandings of mass measurement prior to or during the early years of school. Children's expressions of their own perspectives on their knowledge of measurement can provide insights perhaps not otherwise available and can inform teacher interactions. The research reported here adds a layer to the education community's knowledge of young children's developing understandings of mass measurement.

OPEN-ENDED ASSESSMENT TASKS

Assessment is central to learning (Wiliam, 2010). In a review of research literature on formative assessment, Black and William (1998) discussed using student self-assessment as formative assessment and advocated greater use of formative assessment to improve student learning outcomes. They stated, "self-assessment by the student is not an interesting option or a luxury; it has to be seen as essential" (pp. 54-55). The student self-assessment protocol reported here is an open-ended task which offers insights into young children's thinking about the measurement of mass. Open-ended tasks provide opportunities for teachers to learn about individual student understanding (Sullivan & Lilburn, 2004).

MEASUREMENT UNDERSTANDINGS

In learning to measure, children develop skills such as how to use a balance scale and develop understandings of foundational ideas including awareness of the attribute, comparison, unit iteration, the need for identical units, precision, and number assignment (e.g., Lehrer, Jaslow, & Curtis, 2003; Wilson & Osborne, 1992).

Although research on the measurement of mass is limited, the literature does provide some insights into children's understandings at certain ages. Children play with ideas of mass from as young as 12 months (Lee, 2012), and there is evidence of children demonstrating awareness of the attribute from four to six years (MacDonald, 2012), identifying heavy and light objects prior to instruction at six to eight years (Cheeseman et al., in press), ordering three objects by weight at five years (Brainerd, 1974), quantifying with informal units in the second year of school (age six to seven years of age) and with formal units in the third year of school (Cheeseman, McDonough, & Clarke, 2011), and showing understanding of the relationship between the size of a unit and the number of units needed to measure the mass of an object at six and eight years (Spinillo & Batista, 2009).

However, with the exception of MacDonald (2012), we have been unable to locate literature on children's perceptions of their understandings of mass measurement that is informed by student self-assessment. The current study contributes to this field.

The research question addressed in this paper is: What understandings about measuring mass do young learners portray in response to the *Impress Me* open-ended assessment task?

METHODOLOGY

Research participants

Two hundred and eighty-two Year 1 and 2 students (6 to 8 years of age) and their teachers from three urban and rural schools in Victoria, Australia participated in the study. Each teacher taught a sequence of five lessons on mass measurement (provided by the researchers) to their class, following which they administered the *Impress Me* assessment task.

The assessment protocol

The teachers gave each child a blank piece of A3 paper then read the following prompt:

> We have been doing lots of weighing lately. I want you to show me on this piece of paper all you know about mass and weighing. You can write or draw or do both! Take your time and show your ideas and thinking as best you can.
>
> I want you to "impress me" with all you know about mass and weighing.

The researchers provided further information for the teachers:

> We expect no two responses to be the same and of course there is no one right answer! We want as much or as little as children are individually able to give. (If the issue arises, please note that we are happy to accept children's spelling.)

Children could choose to draw, write, or combine the two. For young children, drawing can potentially be a "powerful medium for discovering and expressing meaning [as it] brings ideas to the surface" (Woleck, 2001, p. 215).

Data collection and analysis

In analysing the children's representations, work samples were read and each element on the page was identified as a response. A grounded theory approach was taken to the data (Strauss & Corbin, 1990). Categories were derived by constantly comparing children's representations. Emerging patterns in the data were identified. In this paper, a selection of themes that reveal complexity in student thinking are discussed and illustrated by inclusion of sample responses. Any non-conventional spelling has been corrected to facilitate readability but sentence structure has not been altered.

FINDINGS

The *Impress Me* responses varied in and across classes and revealed various complexities in children's thinking about measuring mass. In this paper examples of

responses are presented under three themes identified from the data: Equivalence, Measuring with precision, and Volume and mass.

Equivalence

Equivalence is a key understanding in mathematics (Charles, 2005). Equivalence of mass might be judged by hand (hefting), using balance or other scales, and using a range of objects and units. Responses dealing with ideas of equivalence are reported here from the simplest to the most complex levels of thinking.

- Awareness of equivalence with no explicit mention of mass

For example, seemingly referring to use of balance scales, a child wrote, "If you can't see if it's even or not you can look at the arrow. If it's in the middle it's even" and "If it is equal it stays in the same spot". The apparent reference to a balance scale, and to even and equal suggest attention to the attribute of mass but, without a conversation with the child, we cannot be certain.

- Emergent understanding of equivalence

Some children included more explicit mass terminology along with portrayal of balance scales. For example, one student wrote "Equal is things that are light and heavy" and drew a level balance scale labelling it "That's = the same".

- Equivalence with quantifiable materials

For example, a child drew six cubes in one bucket of a balance scale and four in the other, but showed herself adding two more cubes. She wrote: "I'm trying to make these buckets the same".

- Sophisticated understanding of equivalence with quantifiable materials

Children showed that two groups, each with a different number of objects, can be equivalent masses. For example, one student drew balance scales and wrote "10 tiny teddies and 3 Unifix blocks are the same weight".

- Equivalence using formal units

For example, (see Figure 1) a student wrote, "the playdough is 50 grams" (annotated by the teacher) and added, "they're equal" (transcribed by the teacher). The representation suggests also an understanding that two objects of different shapes can weigh the same amount, that is, an understanding of conservation of mass. Another child expressed this idea more explicitly: "Conservation means when you have the same amount but different shapes and make them into a different shape it will stay the same weight".

Figure 1: Student shows equality using grams

Measuring with precision

A further theme identified within the *Impress Me* data relates to children having concern for precision when undertaking mass measurement activities. Under this heading no hierarchy is implied.

- Demonstrated awareness of exactness and inexactness

For example, responses described children's fascination with the term, *approximately*. Explanations included: "close to your answer", "about", and "nearly the same".

Some children talked of the lack of precision of balance scales, in this example demonstrating keen observation of the scale and an awareness of possible limitations:

> Jack and I were [using] the scales. To make it even [we] did big ones and 4 tiny ones in one cup and in the other cup we put 1 pen and it was even!!!! But when we picked up the pen and put it in again and it did not equal so it depends what way you put it in.

- Evaluated the relative accuracy of different scales

For example one child wrote "The balance scale and the digital scale are maybe the best scales to use. Sometimes when you're hefting with the balance scale or the digital scale … the balance scale is wrong and the digital scale is right". Although the child used the term hefting incorrectly, and did not give an in-depth response, there appears to be attention to precision and some level of reflective thinking.

- Referred to the choice of unit and accuracy

For example, one child wrote "Mini teddies are more accurate because they're lighter and they're easier to stop the [balance] scale". As teddies are plastic and cannot be cut, some children combined larger and smaller teddies as informal units to get a more precise measure of the mass of an item. They reported the numbers and different teddies, thus giving a mathematically legitimate, non-conventional measure.

- Referred to weighing accurately in metric units

For example, "Kitchen scales tell you the exact weight something is" and "Digital scales are easy to know how much something weighs because on the bottom it tells the exact grams or kilograms".

- Demonstrated attention to precision

For example, one child wrote, "I learnt that some potatoes weigh approximately the same … some potatoes weigh 40 and another weighs 41 grams".

Volume and mass

A further theme identified within the data was related to the identification that volume and mass are not related. Again, there were differences in responses.

The lack of relationship between volume and mass is a complex aspect of mass measurement that can present challenges for young learners, as expressed with clarity by one child: "There is something that is hard to understand, and that is, there are some things that are small that weigh more than a big thing and … big things are lighter than small things". Some children seemed to be possibly developing an emerging understanding about mass and volume relationships or they were challenged in expressing their understandings, for example, "It doesn't matter if it is small, it was the same"; "Some little things that are big same little thing weigh more grams".

With possible consideration of volume, some children indicated the important understanding that mass cannot be judged by sight, for example, "I know you can't tell something is heavy by looking".

DISCUSSION AND CONCLUSION

The themes shared in this paper suggest complexity in young children's mathematical knowledge; thus the study concurs with previous research (Clements & Sarama, 2007). However, the findings also extend that research by showing complexity of understandings specifically in relation to the measurement of mass.

It is apparent that, given suitable experiences, children of six to eight years of age can potentially engage with important mathematical ideas such as equivalence, precision, and the relationship between measurement attributes. Furthermore, the *Impress Me* assessment instrument provided the opportunity for the children to communicate their knowledge, record reasoning, and demonstrate reflective thinking.

Lehrer et al. (2003) wrote that "Developing an understanding of the mathematics of measure should originate in children's curiosity and everyday experience … and children [should] develop a theory of measure rather than simply collecting measures" (p. 100), with the intention of developing generative and flexible learning. The examples in the paper show that measuring mass can require complex thinking, and that children can develop insights into big ideas of measurement that can potentially be transferred to other measurement attributes.

As illustrated in this paper, based on young children's life experiences and limited formal study of five lessons on mass measurement in the year the study was conducted, there are many nuanced mathematical ideas that the children had come to understand, were developing, or potentially could develop. We recognise that there can be substantial differences in the meanings children construct from shared mathematical experiences and do not claim that all themes we have discussed apply to all children.

But we have shown that young children can potentially engage with sophisticated ideas of mass measurement. Like Stephan and Clements (2003), we question whether the complex mental accomplishments in measuring are always acknowledged in the teaching of mass. But to this end we also agree with the student who stated that "the more you do mass the better you get".

We propose that the *Impress Me* task can be a valuable self-assessment tool, and that its use can potentially benefit the children as well as researchers and teachers. While there may be limitations in its use, it can be one component of the formative assessment undertaken in mathematics classes.

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