Helping Children Understand Measurement Using a Ruler

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Two teachers incorporate research findings into helping a first grade class build the conceptual foundation of the ruler. Assessing students to identify common misconceptions and errors reported in the literature, the teachers design a lesson in which students effectively create their own rulers from square inch cardstock. By creating their rulers, students find similarities between their manufactured rulers and the classroom set. As a result students seem to better understand the "meaning" of the spaces between the numbers on a ruler, and use the ruler more accurately to measure.

The Challenge

The academic year was coming to an end and first grade teachers Mrs. Means and Mrs. Smith had a problem: Too many students did not know how to use a ruler to measure the length of line segments. Though both teachers had taught several lessons using the ruler during the year, many students continued to struggle. Some students would align the "1" on the ruler rather than the "0" with one end of a segment to measure. Others paid no attention to these "beginning" marks; they simply placed the ruler anywhere next to the segment and read the mark nearest to one end. Overall, it seemed that the students did not understand the concept behind the task.

I talked with the teachers and asked them to help me understand their instructional strategies. Following the lead of their classroom text, their methods were very traditional in approach: showing students how to align the ruler, making sure they placed one end of the line at the "0" marking, reading the number on the ruler at the other end of the segment, all followed by much repetition of the task.

As we discussed what researchers found, we were somewhat relieved to know that our children were not all that different in their use of the ruler from many other children.

Review of the Research

So we began to investigate the literature to determine what might be going on, and we found all of our students' mistakes well chronicled. Lehrer (2003) noted the habit of children choosing the "1" mark as the "beginning" with which to measure a line; Hiebert (1984) discussed how children often fail to consider any beginning when aligning the ruler and simply read the mark closest to one end of the segment; Hiebert (1984), and Clements and Battista (1992), observed students measuring in rote fashion without understanding; and several researchers found children focusing on the markings ("1", "2", etc.) rather than the spaces between the markings as the object of the exercise (Barrett, Jones, Thornton, & Dickson, 2003; Stephan & Clements, 2003). As we discussed what researchers found, we were somewhat relieved to know that our children were not all that different in their use of the ruler from many other children.

The research was enlightening for me. I found that using a ruler was not as easy as it seemed. For example, some children may not be ready to use a ruler in a meaningful fashion (Hiebert, 1984). Young children require time to develop what is called "length conservation" – the idea that the length of an object does not change. Without this understanding, there would be no reason to measure a line (the length might be different the next time you

measured it). Children also misinterpret the meaning of the numbers (National Research Council, 2009). Rather than a simple list of counting numbers, the digits on the ruler mark the total number of units of length; thus, one value of the ruler is that one need not "iterate" (repeatedly align a single unit, such as an "inch" length, along an object) to find its length. "Transitivity" (or the idea that one can use a ruler to "transport" the measurement of one object to compare to another object's length) is another aspect students fail to grasp (Kamii & Clark, 1997); some research suggests that transitivity does not develop until ages 7 or 8 (Smedslund, 1963).

Assessing Our Children

Now, armed with this knowledge, we assessed our students to determine which students had what issues so that we could develop a set of tasks to address those issues. The 39 students of both classes were separated into three groups of 10-15 in which each student was given cardstock inch units, a ruler and a set of lines to measure (in inches). As each student measured the lines, I would move about them asking for their answers and how they came upon them. Particular interest was given for their method of measurement. I found that all students were able to conserve length and iterate using the one-inch cardstock units. However, many had issues using the ruler. As the research described, many students seemed to be consumed with finding a number on the ruler that matched the end of each line, with either no regard for the beginning of the line or by placing the ruler so that the line began at "1." One student saw no difference from using the centimeter side and the inch side despite the fact that she was instructed to find the length in "inches." For many there seemed to be little understanding for the purpose of the task. Overall, 11 of the 39 students displayed some or all of the characteristic mistakes found in the research.

Lesson Construction and Execution

Using the assessment results, we devised a plan. For the eleven struggling students we would begin by involving them in a very concrete, conceptual activity for measuring the length of various lines, and then move them to measurement with a ruler. Activities described in a previous journal (Thompson & Van de Walle, 1985) were helpful as a starting point. In the article, the researchers had students measuring with non-standard units (string, paper clips, blocks, etc.) prior to standard units. Eventually, students created their own standard rulers from smaller inch and centimeter units, and these were compared to actual rulers. We thought this to be an excellent idea to build from; however, we wondered if students would understand why the standard units were more important (and composed the ruler) than the non-standard units - the article did not discuss this. Also, we had come across recent research suggesting that non-standard units were being over-emphasized (National Research Council, 2009); thus, we decided to forgo the use of non-standard units and focus on only inches. In addition, we added an original method to this strategy: we would tape the cardstock units together and build our own rulers – each student having a chance to connect the concept of aligning units to the concept of the ruler, right in front of their eyes!

We began with an activity that emphasized the conceptual component of measurement: iterating inch lengths. We decided to use square inch pieces cut from an Ellison Machine to ensure accurate, uniform size (refer to upper right portion of Figure 1). With these and a handout (left in Figure 1) of segments of 1, 2, 3,

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4, 5, and 6 inches in length we asked students to measure these lines using the units. As we went through the activity, I used square sticky notes (of the same color as the inch squares) on the whiteboard to clarify instruction, mimic student work and provide illustrations for discussion.

I asked the students to find out how long the "blue" (3") line was by using the cardboard units. I walked around the room and asked students for their answers and to explain how they found them. We did the same for the "green" (6") segment. For both segments I found all students able to accurately iterate using the inch units.

To ensure that students were making the connection between their taped strips and the individual units, I asked how using this taped strip was similar to or different from using the individual squares.

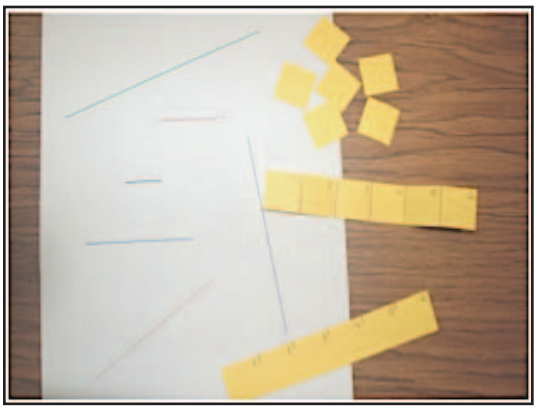

Fig 1 Student-constructed measuring tools

As students completed the last measurement, I had them keep their 6 inch units aligned with the segment. I showed them my work on the whiteboard, aligning the 6 sticky notes to a line that was exactly "6 inches" (sticky notes) long. Then I showed them what we were to do next: I taped my 6 units together. I went from student to student taping together their units into one six inch "ruler." This activity was done in the hope that students would understand the connection between the individual, iterated units and the idea that we could "keep" this iteration with the taped strip; in addition, we were beginning to build a bridge from the iteration of units to the scales on the common ruler (a direct connection between iteration and the ruler, as recommended by Bragg and Outhred, 2004). Once completed, I asked the students to use their strips and re-measure the last segment. I went to each student and all obtained the correct answer, aligning the strip correctly. I asked them if it was easier to use this device rather than the individual squares to measure the line. All agreed this was better: even their little hands had some difficulty aligning the individual units without knocking other previously aligned squares from the line!

To ensure that students were making the connection between their taped strips and the individual units, I asked how using this taped strip was similar to or different from using the individual squares. Several stated that the squares were apart and those in the strips were "together" (a great conceptual connection!).

We decided to measure another line with our strips (the 5" purple line). I observed and asked questions of the students as they accomplished this task. All students had little difficulty correctly aligning the strips and obtaining the correct measures. Some students decided to turn under the last square of the strips in order to make the devices "fit." We discussed this using the whiteboard. I asked if they could do this another way, as some measured the line without turning under the last unit. On the board, we decided we could ignore the last unit and still find the answer, and we all re-measured the line trying it this way.

We moved to the red (2") line. I asked the students to measure and ignore the additional units again. No one seemed to have difficulty with this method, though a few still preferred to turn the squares under.

I went back to the 5" line and I measured it on the board. I counted the number of squares and told the students that I was going to try something. Instead of having

to always count the squares, I was going to number them so I wouldn't have to always count. I placed the numbers 1, 2, 3, 4, 5, and 6 in their "traditional" places. I then demonstrated how this would save me time – I would no longer have to count the squares! I asked each child to number their squares, and to place the number in the upper right corner of each unit. The students did this, though some placed the number in the center of the unit (which was deemed acceptable assuming the students understood the connection between the numbers and the units).

With our numbered strips, we re-measured the 2" line with no difficulty. We discussed how this was easier than counting the units. I then passed out 6" strips very similar to the ones they had created, made of the same cardstock as their taped strips (middle right in the photograph). The only difference was that I had made these strips of one piece and I placed lines from the top to the bottom of the strips to mark the division between units. I asked the students to number each unit as we had done previously, and we measured the 2" line again followed by the orange (4") line. I walked around and observed no difficulties with this activity; the students seemed to understand the connection of these strips with the individual units we used earlier.

I told the class that when I made these strips I had become rather "tired" of drawing the lines "all the way" down the width of the strips. So when I made a second set of strips, I decided to make the lines shorter (bottom right of photograph). I also wrote the number of each unit on the strips. I passed these new strips to the students. Several students noted that they looked like "rulers," the plastic rulers they had used previously in class – another great connection! We used these rulers to find the length of the orange line again, and students did very well.

Finally, I handed out their familiar plastic 12" rulers. I asked them to compare the rulers with the cardstock strips we just used. As would be expected, several said that the strips were smaller! I asked if they could see how we could use the plastic rulers in place of our strips to find the measure of lines (again, making the direct connection suggested by Bragg and Outhred, 2004), and with their approval we did just that. We re-measured several lines with the rulers. The students displayed no difficulties! Students measured all of the lines, aligning the ruler correctly and identifying the correct length for each line! This task concluded the 35 minute lesson.

Several hours later, Mrs. Means and Mrs. Smith gave the students a quiz with the plastic rulers, asking the students to measure four different size lines. Of the 11 students who had participated in the described activity, 6 measured all four lines correctly and 1 other measured 3 of 4 correctly! Of the remaining 4 students, two measured two lines correctly, 1 measured one line correctly, and one failed on all tries. For a very brief and sometimes hurried lesson, the results were well-received!

Conclusions and Recommendations

The lesson was rushed a bit due to uncontrollable time constraints. As a unit, I would recommend that this activity be split into at least two separate lessons of 30-40 minutes each, if not developed in smaller lessons throughout the year. It also may not be necessary to provide a cardboard strip with marks that are not completely drawn across the width; it might be just as easy to move to the plastic rulers at that place in the lesson and ask students to describe the similarities between the plastic rulers and the strips. Another idea would be to have children measure with the squares and use the squares to create bar graphs which can be used to analyze and compare lengths of

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different objects; through activities such as this, children would have a chance to build the purpose of the inch units, creating pseudo-rulers with the charts, bringing meaning to such alignments and their value.

This lesson built upon the concept of measuring lines using iterated lengths, and successfully built a bridge from this concept to the more abstract ruler. Incorporating other researchers' findings was a central feature in the creation of the lesson. As a lesson and a means to create lessons, this activity will become a learning tool in my Early Childhood Mathematics Methods course.

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