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ABSTRACT

This study involved 3 days of teaching in two fourth-grade classes. A pretest and a posttest were given consisting of (1) a NAEP item asking for the length of a line drawn next to a ruler, (2) a Piagetian unit-iteration task, and (3) the measurement of an object with a ruler that had the "0" mark away from its edge. It was found in the pretest that 86% of the children had constructed the logic of unit iteration but that most of them could not use a ruler correctly. The posttest revealed that, although there was progress, the problems found in the pretest persisted among a third to a fourth of the children. These problems were all related to the initial unit of measurement. (Author)

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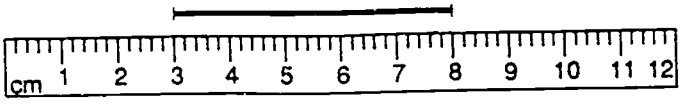
This study involved three days of teaching in two fourth-grade classes. A pretest and a posttest were given consisting of (a) a NAEP item asking for the length of a line drawn next a ruler, (b) a Piagetian unit-iteration task, and (c) the measurement of an object with a ruler that had the "0" mark away from its edge. It was found from the pretest that 86% of the children had constructed the logic of unit iteration but that most of them could not use a ruler correctly. The posttest revealed that, although there was progress, the problems found in the pretest persisted among a third to a fourth of the children. These problems were all related to the initial unit of measurement.

The 1985-86 National Assessment of Educational Progress (NAEP) revealed that only 14% of the third graders and 49% of the seventh graders chose the correct answer of 5 cm as the length of the line shown in Fig. 1 (Lindquist & Kouba, 1989). The 1990 NAEP included a similar item and produced similar findings (Mullis, Dossey, Owen, & Phillips, 1991).



Item	Percent Responding[a] Grade 3	Grade 7
How long is this line segment?[b]		
3 cm	4	1
5 cm	14	49
6 cm	31	37
8 cm	30	9
11 cm	6	2
I don't know.	15	2

[a] The response rate was .80 for grade 3 and .97 for grade 7.

[b] An actual centimeter ruler was pictured.

Fig. 1

The purpose of this paper is to explain why the use of a ruler is difficult by describing findings from a three-day teaching experiment in two classes of fourth graders. I first gave a pretest consisting of three parts: (a) the NAEP question shown above, (b) a Piagetian task of unit iteration, and (c) a measurement task requiring the use of a ruler. I then joined two teachers in their respective classrooms as they engaged in activities that required the use of a ruler. The experiment ended with a posttest that shed new light on children's difficulty in using rulers.

	Pretest n=44	Posttest n=44
NAEP question		
5 cm	45	64
6 cm	48	34
8 cm	5	2
11 cm	2	0
Unit-iteration task	86	95
Tasks requiring the use of a ruler		
Ruler shown in Fig. 3		
Alignment with "0" (4 3/4 inches) or ignoring all numerals, counting intervals, and giving correct answer	18	84
Alignment with edge of ruler (3 3/4 inches)	57	11
Alignment with "1" (5 3/4 inches)	9	5
Alignment with 1/8 inch to left of 0 (4 1/2 inches)	16	0
Ruler shown in Fig. 5 (used only in posttest)		
Alignment with implicit 0 (the correct answer of 13 cm)		73
Alignment with edge of ruler (12+ cm)		14
Alignment with "1" (14 cm)		14

The Pretest (given in individual interviews)

The NAEP question. As can be seen in the preceding table, 45% of our fourth graders gave the correct answer of 5 cm, but 48% counted the numerals 3-8 on the ruler and said the line was 6 cm long. Half of our fourth graders thus demonstrated that they counted points rather than intervals.

A unit-iteration task. This task, based on Piaget, Inhelder, and Szeminska (1948/1960) and Kamii (1991), was given to find out if our children had constructed the logic of unit iteration. Unit iteration here refers to the ability to use a small, flat block (1.25 x 1.25 inches) repeatedly to determine whether or not the two lines in an inverted T (Fig. 2) have the same length. Both lines were 4.75 inches long, but the vertical one looked longer because of an optical illusion. The logic of unit

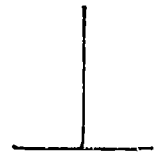


Fig. 2

iteration is necessary for a child to use and understand conventional units (intervals) such as inches and centimeters. As can be seen in the table, 86% of our fourth graders demonstrated the logic of unit iteration.

Fig. 3

A task requiring the use of a ruler. To find out how children used the left extremity and "0" point of a ruler, I asked them to measure the horizontal line of the inverted T with a ruler like the one in Fig. 3. Only 18% of our fourth graders gave the correct answer of "about 5 (or 4 3/4) inches." The most common error (made by 57%) was to align the edge of the ruler with the beginning of the line being measured, read the numeral corresponding to the end of the line, and say that the line was "about 4 (or 3 3/4) inches long." Two other kinds of errors also demonstrated the difficulty of the initial interval. One was to align the "1" on the ruler with the beginning of the line and to say that the line was "about 6 (or 5 3/4) inches long." Nine percent of our fourth graders made this error. The second type of error was to align the beginning of the line with a mark on the ruler about 1/8 inch to the left of the "0" mark. Sixteen percent of our fourth graders did this and said the line was "about 4 1/2 inches long." These children meant to align the "0" mark with the beginning of the line but thought that the point 0 was directly above the numeral 0 (see Fig. 3).

The overall conclusion drawn from the pretest was that since most of our fourth graders had constructed the logic of unit iteration, the use of a ruler was developmentally appropriate to teach. More than half of the children had trouble thinking about the first unit (an interval), but this difficulty seemed superficial compared to the deep logic of unit iteration that most of our children demonstrated.

Three Days of Teaching

The measurement activities recommended by textbooks have two major weaknesses. First, textbooks ask questions such as "How many centimeters wide is your desk?" that are irrelevant to children. Second, they ask "How many?" without giving children any reason for measuring things. Our classroom activities were the following three kinds that were more purposeful and interesting.

Measuring to compare. An example of this kind of activity was inspired by Opt: An Illusionary Tale (Baum & Baum, 1987), a collection of pictures such as the one in Fig. 4 asking if the height of the hat is greater than the width of the brim. Throughout the three days of teaching, we asked the children to use a ruler like the one in Fig. 3.

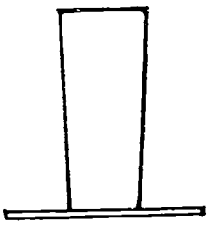


Fig. 4

Measuring to draw. We asked the children to make drawings similar to Fig. 4 but with different dimensions, to take home and amuse their families.

Measuring to make something. The intriguing object we suggested to the children to make was a "Magic Calendar." However, a different arts-and-crafts activity could also have been used necessitating the accurate use of a ruler.

A particularly important part of our constructivist teaching was to avoid direct teaching and, instead, encourage the exchange of points of view among children. As Piaget (1979) said, "The confrontation of points of view is already indispensable in childhood for the elaboration of logical thought, and such confrontations become increasingly more important in the elaboration of sciences by adults (p. vii)." When a child said, "My ruler is wrong," to another child, for example, we encouraged the second child to respond. A frequently heard response was: "The ruler doesn't make any difference because an inch is an inch. See, I'll show you. . . ."

We learned much about children's ways of thinking by interacting with them in the classroom. For example, when they had trouble figuring out how to use our ruler (Fig. 3), they asked us for help. A possible reaction in such a situation was to find out "where the child was" by saying, "Would you show me an inch--an example of an inch." Some children responded by pointing to the "1" on the ruler, suggesting that an inch to them was a point or a numeral rather than an interval. When this happened, we usually said, "I thought an inch was about this long," showing an interval between two fingers.

Many children aligned the edge of the ruler with the edge of the object being measured and counted the intervals instead of using the numerals on the ruler. When we saw this behavior, we sometimes asked, "Wouldn't it be easier to put the 0 on the edge like this (demonstrating) so you could just read the number at the other end?" Some children responded

with a "No." Others slid the ruler to the left, past the 0, and aligned the edge of the object with the "1" on the ruler! As they later explained during the whole-class discussion, "Zero doesn't count," and "When you count, you don't say 'zero-one-two.' You say 'one-two-three.'" We thus learned that some children's belief that "zero doesn't count" was preventing them from thinking about the initial interval.

The Posttest

As can be seen in the table presented earlier, the children did better on the posttest, but a large percentage, 34%, continued to choose the answer of 6 cm on the NAEP question.

Fig. 5

The "acid test" required the use of an unfamiliar ruler (see Fig. 5). The marks on this ruler started about 6 mm away from the edge, and the 0 point was not numbered. Another novelty was that this was a centimeter ruler, and the children had been using only inches. Although 73% of our children gave the correct answer of 13 cm by using the unfamiliar ruler correctly, the errors described earlier persisted among the other students. Fourteen percent aligned the edge of the ruler with the edge of the object and reported a length of "a little more than 12 cm." Another 14% aligned the "1" mark with the edge of the object and said it was 14 cm long.

Conclusion

Measurement of length is introduced in kindergarten and taught repeatedly in subsequent years according to most state curriculum guides and nationally distributed textbooks. I thought that the use of a ruler would be more appropriate and easy to teach in fourth grade because 86% of our children had constructed the logic of unit iteration. However, this logic turned out to be far from sufficient for the learning I expected.

Mathematics educators, including the authors of the Standards (NCTM, 1989), say that the way to build a conceptual foundation for the use of instruments is to provide experiences with concrete objects and to ask children to estimate how many units they will find by counting them. The experiment described above shows the need to examine children's thinking more deeply and precisely. The problems of the initial unit, the edge of the ruler, the "0" point, and the "1" have been observed by many teachers and some researchers such as Héraud (1989) and Bright and Hoeffner (1993).

Further research is necessary to find out how best to encourage children to modify their thinking about these aspects of measurement.

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