Understanding basic concepts in spatial measurement

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To help prevent students from having misconceptions about measurement, Jack Smith and his colleagues at Michigan State University (MSU) are analyzing curricula that elementary school teachers and children currently use in schools to learn spatial measurement (length, area and volume). Credit: Thinkstock

In a first or second grade classroom, a teacher asks students to take a ruler and measure (in inches) the length of a rectangular block. A student aligns the "0 inch" mark of the ruler with the end of the block, and counts the number of inches from the end of the ruler to where the block ends.

"It's three inches," the student says.

In reality, the block is two inches. The student counted the 0 inch mark as part of the measurement, instead of starting at the 1 inch mark. The child moved from one end of the object to the other, but counted the inch marks on the ruler, instead of the intervals of space between them.

This is just one of common misconceptions that elementary-school-aged children make when learning how to measure various objects.

To help prevent students from having these misconceptions, Jack Smith and his colleagues at Michigan State University (MSU) are analyzing curricula that elementary school teachers and children currently use in schools to learn spatial measurement--length, area and volume.

Smith explained the goal of their research is to inform the revision of curriculum materials, guide the design and implementation of professional development, pre-service education to improve the use of existing curriculum materials and enrich the nation's research capacity to build usable knowledge in this specific area of need in mathematics education.

The following example illustrates a misconception when determining the perimeter of a 2-D shape: A student is asked to find the perimeter (the length of the continuous line forming the boundary of a closed geometric figure) of this

2-D rectangle. The student is told that the perimeter of the rectangle can be found by surrounding the rectangle with square tiles, including tiles at each of the four corners. The student claims that the perimeter of the rectangle is 22 tiles. However, the actual perimeter is 18 tiles. The student is not distinguishing the edges of the tiles as length units from the square tiles that are area units--the ability to visualize the difference is crucial in understanding what one is measuring. Credit: Courtesy of Jack Smith, MSU

To achieve this, Smith and his team are examining three elementary mathematics curricula, "Everyday Mathematics," "Scott-Foresman-Addison Wesley Mathematics (Michigan edition)" and "Saxon Math," and applying what they have learned about teacher professional development with state-wide partners in Michigan, teacher education at MSU and research with partners at other universities. They also are working with curriculum authors to revise measurement content to align with the Common Core State Standards in Mathematics and support stronger learning opportunities for students.

"Current curriculum materials generally focus on teaching students how to measure, but attend little to why those procedures work," said Smith. "The result is that what is not understood in the first place is easily forgotten. This procedural focus also means that students have a much harder time adapting to measurement situations that they have not seen and practiced in school. That's because they have learned the steps in standard, practiced situations but they don't know why those are there or how to adapt them."

Teaching children about spatial measurement is crucial in understanding the physical world and for practical application, such as being able to measure objects accurately.

"There are two kinds of quantities in the world that mathematics and

numbers represent," said Smith. "There are collections of objects (discrete quantity) and there are measurable objects (continuous quantity). Currently, in U.S. classrooms we focus mostly on the former and avoid the latter. This means that less attention to measurement fails to prepare students to deal practically with the physical--that is, to measure things and think about measurement in their everyday world. That's the immediate impact."

Smith added that learning about these foundations of measurement further prepares students to comprehend more advanced mathematics and science. "A lot of math and science is not easily accessible without understanding the basics of measurement, which in this country and most others is learned in the study of spatial measurement," said Smith.

To better teach measurement, Smith outlines a variety of techniques.

"First, using length as an example, children need to be able to see, think about and talk about length as an attribute of objects and distance," said Smith. "That is, they have to be able to 'see' length. This is not a step that can be taken for granted."

For instance, Smith provides the following example (see image in the right side-bar): A student is asked to find the perimeter--the length of the continuous line forming the boundary of a closed geometric figure--of a 2-D rectangle. The student is told that the perimeter of the rectangle can be found by surrounding the rectangle with square tiles, including tiles at each of the four corners. The student claims that the perimeter of the rectangle is 22 tiles. However, the actual perimeter is 18 tiles. The student is not distinguishing the edges of the tiles as length units from the square tiles that are area units--the ability to visualize the difference is crucial in understanding what one is measuring.

Smith explained additional characteristics of effective instruction and

curricula for elementary school that include "attention to core conceptual principles that underlie and justify measurement procedures; specific attention to understanding how measurement tools and formulas work, as many of the nation's fourth graders do not understand how rulers work; consistently asking kids to present what they did to solve problems and why those methods worked or not; tracing common conceptual principles across the measurement of different physical quantities (spatial and non-spatial); and attention to the importance of motion in measurement."

Another key in helping elementary-school-aged children learn, is making sure that they have a strong mathematics foundation in pre-school. Smith explained, "For spatial measurement, a strong pre-school focus on qualitative comparisons of spatial quantities as attributes of everyday objects, e.g., is the coat rack taller than the door? How can we tell?, lays the groundwork for exploring measurement issues in more exact ways, e.g., how much taller is the coat rack than the door?"

Smith suggests that ultimately, measurement plays a large role in how children understand the foundations of mathematics. "It has been an axiom for some time that counting and numbers, and operations on numbers is the heart of elementary mathematics education," said Smith. "But there is evidence that this is a historical choice rather than a clearly justified application of knowledge of human development."

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