ED482721 2003-00-00 Fundamental Skills in Science: Measurement. ERIC Digest.

ERIC Development Team

www.eric.ed.gov

Table of Contents

If you're viewing this document online, you can click any of the topics below to link directly to that section.

ERIC Identifier: ED482721
Publication Date: 2003-00-00
Author: Haury, David L.
Source: ERIC Clearinghouse for Science Mathematics and Environmental Education Columbus OH.

Fundamental Skills in Science: Measurement. ERIC Digest.

"When you can measure what you are speaking about and express it in numbers, you

know something about it."

Lord Kelvin, speaking to the Institution of Civil Engineers, May 3, 1883

To suggest that measurement is important to doing science seems at best an understatement. It has been acknowledged that "while not every scientific fact is a numerical one, nor every scientific theory a predictor of numerical magnitudes, so many are that we cannot conceive of modern science without the process of measurement (Goldstein & Goldstein, 1978, p. 231). Crosby (1997) has gone further to suggest that the interlinked concepts of quantification and measurement are at the core of Western thought, with the development of measuring instruments preparing the way for the modern scientific revolution. As he characterized it, "the West's distinctive intellectual accomplishment was to bring mathematics and measurement together and to hold them to the task of making sense of a sensorially perceivable reality" (p. 17).

One has only to glance around home or the workplace to realize that measurement is also fundamental to everyday life. We use thermometers to check for fevers when our children are sick; we use scales to weight vegetables in the grocery store, or to weigh ourselves at home; and we pay bills based on metered services, such as electrical power, natural gas, water, heating oil, or telephone time. We use a speedometer while driving, and we use measuring cups in the kitchen. Medications are dispensed in standard amounts, and shoes come in standard sizes.

Measuring instruments are common items of equipment in science classrooms, so it is interesting to note that student use of equipment in science classes apparently contributes to increased achievement (O'Sullivan, Reese, & Mazzeo, 1997) as measured by the National Assessment of Educational Progress. It had earlier been reported that the more different types of equipment used by students in science, the higher their level of achievement (Jones et al., 1992). If measurements are common in daily life, and using the equipment of measurement seems to foster increased achievement, one might expect student understanding of measurement to be relatively high.

Performance in measurement was among the areas examined by the most recent repeat of the Third International Mathematics and Science Study (TIMSS), and the findings of this study are available online at http://timss.bc.edu/timss1999i/publications.html. Though U.S eighth grade students scored above the international average in some areas, they scored below the international average in "measurement". This seems unfortunate when one considers the fundamental importance of measurement, both to science and daily life. Is measurement not adequately covered in science or mathematics curricula?

MEASUREMENT AND CURRICULUM STANDARDS

Reform of science education has been greatly influenced nationwide by the "Benchmarks for Science Literacy" (Project 2061, 1993) and the "National Science Education Standards" (NSES, National Research Council, 1996). Interestingly, there are few explicit expectations in these seminal documents related to measurement, though attention to measurement is implied in several statements. For instance, the "Benchmarks" state that students should know the following:

* Tools such as thermometers, magnifiers, rulers, or balances often give more information about things than can be obtained by just observing things without their help. (Grades K-2, p. 10)

* Measuring instruments can be used to gather accurate information for making scientific comparisons of objects and events and for designing and constructing things that will work properly. (Grades 3-5, p. 45)

* Read analog and digital meters on instruments used to make direct measurements of length, volume, weight, elapsed time, rates, and temperature, and choose appropriate units for reporting various magnitudes. (Grades 6-8, p. 294)

* The effects of uncertainties in measurements on a computed result can be estimated. (Grades 9-12, p. 214)

The NSES also includes attention to measurement: one component of the "Unifying Concepts and Processes" is "constancy, change and measurement" with quantification, scale, and rates being concepts identified. Following is a sample key idea: "Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is knowing when to use which system. For example, a meteorologist might use degrees Fahrenheit when reporting the weather to the public, but in writing scientific reports, the meteorologist would use degrees Celsius."

Finally, Content Standard A, "Science as Inquiry", includes understandings such as the following for grades 9-12: "Scientists rely on technology to enhance the gathering and

manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used."

From a mathematics perspective, measurement is the assignment of a numerical value to an attribute of an object, or the assignment of a number to a characteristic of a situation. The "Principles and Standards for School Mathematics" (National Council of Teachers of Mathematics, 2000), provide an array of specific expectations for grades Pre-Kindergarten through 12 related to the following two measurement standards:

* Understand measurable attributes of objects and the units, systems, and processes of measurement.

* Apply appropriate techniques, tools, and formulas to determine measurements.

The details of grade-specific expectations can be reviewed online at http://standards.nctm.org/document/index.htm. Key concepts related to measurement and measuring instruments include the following: units, measurement systems, measurement tools, error of measurement, accuracy, precision, calibration, scales, rate, estimation, scientific notation, and significant figures.

Given the influence of these reform documents on state curriculum frameworks, and the evidence of a strong link between school curriculum and learning in science and mathematics (Schmidt, et al., 2001), teachers must consider if explicit instruction in measurement is adequate, given the importance of measurement to the processes of science.

STUDENT DIFFICULTIES AND MISCONCEPTIONS

Long and Kamii (2001) found that "by fourth grade less than half the students were able to construct units and separate their own actions from that of an instrument used to measure time." Following are some difficulties and misconceptions reported by Hapkiewicz (1992): * Measurement is only linear. * The metric system is more accurate than other measurement systems (such as the English system). * You can only measure to the smallest unit shown on the measuring device. * An object must be "touched" to be measured. * The only way to measure time is with a clock or a watch. * Only the area of rectangular shapes can be measured in square units. * Surface area

can be found only for two-dimensional objects. * You cannot measure the volume of some objects because they do not have regular lengths, widths, or heights. * The density of two samples of the same substance with different volumes or shapes cannot be the same.
Fisher (2002) has reported providing specific guidance to students to improve the accuracy, precision, and reliability of measurements.

Unfortunately, it is not just students who have difficulties and misconceptions when it comes to measuring. Sterling and Hall (2000) examined the ability of graduate preservice science teachers to make accurate measurements using simple procedures and common laboratory equipment. These students held misconceptions related both to the processes of measuring and to interpreting results. For instance, only 12 of 195 prospective middle school and high science teachers reported accurate measurements for the length of a plastic straw.

THE CHALLENGE TO SCIENCE TEACHERS

The disparity between mediocre student performance on tests of measurement on one hand and the fundamental importance of measurement to science and everyday life on the other presents a challenge for science teachers. Teachers must examine both their curriculum and their own instruction to insure that measurement gets the developmentally appropriate attention it deserves at all grade levels. Because measurement is such a common feature of modern life and seems nearly intuitive to adults, there seems a danger that explicit, direct instruction in measurement and the instruments of measurement may get less attention than is warranted unless teachers maintain continuous attention both to the concepts and the processes of measurement at all grade levels.

RESOURCES

The ERIC database can be electronically searched online at: http://ericir.syr.edu/Eric/adv_search.shtml. It is recommended that standard indexing terms, called ERIC Descriptors, be used whenever possible to search the database. The terms "measurement," "error of measurement," and "measurement equipment" are ERIC Descriptors, so these terms could be combined with other Descriptors, such as "science education" or "science activities."

Books

The NSES include a strand relating to the historical dimension of science topics, so one way to nurture a greater understanding of the role of measurement in modern science is through the lens of history. Following are two recent books that focus attention on the interconnections of science, measurement, and culture:

* "The measure of all things," by Ken Alder, relates the human drama of two scientists who forever changed the way we examine our world.

* "Measuring America: How the Nation was Shaped by the Greatest Land Sale in History," by Andro Linklater, recounts the largest land survey in history and how decisions about systems of measurement led to battles and arguments.

Web Resources

* The Math Forum Library: Measurement

http://mathforum.org/library/topics/measurement/

* Beginner's Guides to Measurement

The UK's National Measurement Laboratory

http://www.npl.co.uk/npl/publications/posters.html

* Measurement Skills and Data Analysis: Teacher Resource Guide

http://gse.gmu.edu/centersoffices/crest/guide.htm

* GLOBE Program Protocols for Measurements
http://www.globe.gov/fsl/html/templ.cgi?measpage&lang=en&nav=1

REFERENCES

Crosby, A. W. (1997). "The measure of reality: Quantification and Western society, 1250-1600." New York: Cambridge University Press.
Fisher, N. (2002). Teaching accuracy and reliability for student projects. "Physics Education," 37 (5), 371-375.

Jones, L. R., Mullis, I. V., Raizen, S. A., Weiss, I. R., & Weston, E. A. (1992). "The 1990 science report card." Washington, DC: National Center for Educational Statistics.

Goldstein, M., & Goldstein, I. F. (1978). "How we know: An exploration of the scientific process." New York: Plenum Press.

Goldstein, H., Gross, J. L., Pollack, R. E., & Blumberg, R. B. (1996). "The scientific experience." (Unpublished manuscript). Chapter 3, "Measurement," is available online at http://www.mendelweb.org/MWjg3.1.html

Hapkiewicz, A. (1992, Winter). Finding a List of Science Misconceptions. "MSTA Newsletter," 38, 11-14.

Long, K., & Kamii, C. (2001, March). The measurement of time: Children's construction of transitivity, unit iteration, and conservation of speed. "School Science and Mathematics," 101 (3), 125-131.

National Council of Teachers of Mathematics. (2000). "Principles and standards for school mathematics." Reston, VA: Author. [Available online at http://standards.nctm.org/document/index.htm]

National Research Council. (1996). National science education standards. Washington, DC: National Academy Press. [Available online at http://www.nap.edu/readingroom/books/nses/html/]

O'Sullivan, C. Y., Reese, C. M., & Mazzeo, J. (1997). "NAEP 1996 mathematics report card for the nation and the states (NCES 97-488)." Washington, DC: National Center for Educational Statistics.

Project 2061, American Association for the Advancement of Science. (1993). "Benchmarks for science literacy." New York: Oxford University Press.

Schmnidt, W. H., McKnight, C. C., Houang, R. R., Wang, H., Wiley, D. E., Cogan, L. S., & Wolfe, R. G. (2001). "Why schools matter: A cross-national comparison of curriculum and learning." San Francisco, CA: Jossey-Bass.

Sterling, D. R., & Hall, A. L. (2000). "Preservice middle and secondary school teachers' misconceptions about making measurements using laboratory instruments." (A paper presented at the 1999 Annual International Conference of the Association for the Education of Teachers in Science, Austin, Texas, January 14-17). [ED 446 902]

This digest was funded by the Office of Educational Research and Improvement, U.S. Department of Education, under contract no. ED-99-CO-0024. Opinions expressed in this digest do not necessarily reflect the positions or policies of OERI or the U.S. Department of Education.

__

Title: Fundamental Skills in Science: Measurement. ERIC Digest.
Document Type: Information Analyses---ERIC Information Analysis Products (IAPs) (071); Information Analyses---ERIC Digests (Selected) in Full Text (073);
Descriptors: Measurement, Metric System, Science Education, Science Process Skills
Identifiers: ERIC Digests