The Mathematics Educator
2001, Vol 6, No. 1, 17-21

Understanding the Standards-based Reform Movement in School Mathematics

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The "standards-based reform movement" now underway in many countries, states, and schools is the outcome in response to the calls for change. To understand the movement involves clarifying four aspects of the changes being proposed. First, the shift in epistemology about the learning mathematics must be understood. Second, the systemic notions about schooling that follow from that shift need to be considered. Third, appropriate evidence related to the notions of schooling practices should be documented. And finally if the changes in instruction on student learning is to be determined, new means of assessment need to be developed.

Shift in Epistemology

Underlying the calls for reform is the fact that during the past half century the new electronic technological innovations have changed societies from an "industrial age" to an "information age", and the principle role of mathematics in contemporary society has changed from accounting to mathematical modeling. The central tenet of this shift is that for students to be prepared for the demands of the "information age" they must become mathematically literate. The term "literacy" refers to the human use of language (Gee, 1998). In fact, each human language and each human use of language has both an intricate design tied in complex ways to a variety of functions. For a person to be literate in a language implies that the person knows many of the design resources of the language and is able to use those resources for several different social functions. Analogously to become mathematically literate implies that students not only must learn the concepts and procedures of mathematics (its design features) they must learn to use such ideas to solve non-routine problems and learn to mathematize in a variety of situations (its social functions). The epistemological shift involves moving from mastery of concepts and procedures to student understanding of the concepts and procedures and their ability to mathematize problem situations.

Reform Schooling

For society to have mathematically literate citizens all students can and must learn more and somewhat different mathematics than has been expected in the past. In particular, all students need to have the opportunity to learn important mathematics regardless of socio-economic class, gender, and ethnicity. Also, some of the important notions we expect students to learn have changed due to changes in technology and new applications. In particular, technological tools increasingly make it possible to create new, different, and engaging instructional environments. The critical learning of mathematics by students occurs as a consequence of building on prior knowledge via purposeful engagement in activities and by discourse with other students and teachers in classrooms. In classrooms where the emphasis of instruction has shifted from mastery of facts and skills to understanding, students become motivated to learn and achievement at all levels increased. In such classrooms, understanding can be characterized in terms of five interrelated forms of mental activity from which the mathematical and scientific understanding emerges (Carpenter & Lehrer, 1999):

(1) constructing relationships,
(2) extending and applying mathematical and scientific knowledge,
(3) reflecting about mathematical and scientific experiences,
(4) articulating what one knows, and
(5) making mathematical and scientific knowledge one's own.

Since all learning occurs as a consequence of experiences, and all humans have a variety of experiences, virtually all complex ideas in mathematics are understood by a student at a number of different levels in quite different ways. Furthermore, a student's level of understanding will change as a consequence of instructional experiences. Thus, the challenge is how to create classroom experiences so that a student's understanding grows over time. As recently stated in *How People Learn*:

> Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classrooms (Donovan, Bransford, & Pellegrino, 1999, p. 10).

The instructional consequences of this perspective are that students should begin their investigations with a problem that needs to be addressed and that makes sense to them. The initial instructional activity should be experientially real to students so they are motivated to engage in personally meaningful mathematical work. This step involves raising questions about the problem situation. Hypothesis generation is a critical aspect of mathematical and scientific reasoning that rarely has been taught. Furthermore, each activity should be justifiable in terms of some potential end points in a learning sequence. Paul Cobb (1994) state:

> This implies that students' initially informal mathematical activity should constitute a basis from which they can abstract and construct increasingly sophisticated mathematical conceptions. At the same time, the starting point situations should continue to function as paradigm cases that involve rich imagery and thus anchor students' increasingly abstract mathematical activity. (p. 23-24)

Next students need to identify information and procedures they could use to answer their questions. Cobb then goes on to argue that "Instructional sequences should involve activities in which students create and elaborate symbolic models of their informal mathematical activity. This modeling activity might involve making drawings, diagrams, or tables, or it could involve developing informal notations or using conventional mathematical notations" (p. 24). Finally, one needs to build a coherent case about the quality of one's answer, developing an appreciation of standards of evidence and appropriate forms of argument.

The point is that, with appropriate guidance from teachers, a student's informal models can evolve into models for increasingly abstract mathematical and scientific reasoning. The development of ways of symbolizing problem situations and the transition from informal to formal semiotics are important aspects of these instructional assumptions. The fact is that the standards-based vision of reform should be focused on this non-routine pattern of instruction that allows students to become mathematically literate.

Appropriate Evidence about Changes in Schooling Practices

The problem with this vision of school mathematics, as outlined in the previous paragraphs, is that the ideas are ideas put forward by educational leaders, policymakers, and professors about what mathematical content, pedagogy, and assessments should be. Implementation of such ideals can be undermined by a number of factors. In fact, as Labaree pointed out that during the past century calls for reform in the U.S. have had "remarkably little effect on the character of teaching and learning in American classrooms" (1999, p. 42). In typical classrooms the mathematical content is cut off from practical problem situations and taught in isolation from other subjects, students are differentiated by ability and sequenced by age, instruction is grounded in textbooks and delivered in a teacher-centered environment. Instead of changing conventional practices the common response to calls for reform has been the "nominal" adoption of the reform ideas. Schools have used the reform labels but did not follow most of the practices advocated (Romberg, 1985). Thus, to document the impact of any reform efforts in classrooms one needs to examine the degree to which the reform vision actually has been implemented.

Assessing Mathematical Literacy

To be consistent with the standards-based vision the quality of student performance should be judged in terms of whether students are mathematically literate. This means there should information gathered about what concepts and procedures students know with understanding, and how students can use such knowledge to mathematize a variety of non-routine problem situations. Only then can one judge whether student performance meets the reform vision, and in turn whether the changes meet society's needs. Unfortunately the existing instruments commonly used to judge student performances in mathematics were not designed to assess mathematical literacy. Too often tests only count the number of correct answers a student can answer to questions about knowledge of facts, representing and recognizing equivalent representations, recalling mathematical objects and properties, performing routine procedures, applying standard algorithms, manipulating expressions containing symbols and formulae in standard form, and doing calculations. As such at best they measure a student's knowledge of some of the "design features" associated with mathematical literacy. It is questionable as to whether such instruments measure understanding of such features. Additionally they do not make any serious attempt to assess student capability to mathematize. Thus, to assess the intended impact of standards-based reforms in mathematics a new assessment system will need to be developed.

Fortunately there is one new international assessment framework emphasizing literacy (reading, mathematical, and scientific) that has been designed for the Programme for International Student Assessment (PISA) by the Organisation for Economic Cooperation and Development (OECD, 1999). This program has been designed to monitor on a regular basis the mathematical literacy of students as they approach the end of secondary school. Tests developed from this framework were administered in 2000 in some 30 countries, and will be again in 2003 and 2006. It is premature to judge the quality of this program, but the framework they are using fits the reform epistemology. In particular, the notion of "big ideas" such as chance, change and growth, space and shape, etc., and the designation of three "competency classes" defining the type of thinking skill needed are consistent with the reform rhetoric. The three competency classes are: (1) tasks requiring simple computations or definitions, (2) tasks requiring connections be make to solve straightforward problems, and (3) tasks requiring mathematical thinking, generalization, and insight.

Summary

To understand the standards-based reform movement in school mathematics one should be aware that the movement calls for:

- a shift in epistemology towards mathematical literacy,
- a shift on schooling practices consistent with mathematical literacy, and
- that assessments aligned with the mathematical literacy need to be developed and used to document student learning.

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