Mathematics Learning for All
How Can It Be Done?

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Abstract[1]

Background

The perspective of this presentation is tied directly to American experience, including at least a century of cyclic reform efforts in mathematics education (not all in the experience of the author, of course). One hopes that an international audience can benefit at least in the sense of not repeating all of our mistakes.

Over the past two generations, American colleges have seen a dramatic shift in the demographics of college-going, stimulated in part by ever-rising expectations, needs, and opportunities for those pursuing "the American dream." For much of that time, college faculties responded by "watering down" courses that had been designed for an elite population. For example, Calculus for Business and Biology Students was created by taking all the "hard stuff" out of Real He-Man Calculus for Mathematics, Engineering, and Hard Science majors, otherwise known simply as *Calculus*. The litany of problems this generated is well-known: bored and alienated students, high failure rates, rapid growth of remedial programs, frustrated teachers, and so on.

Reappraising reality

Only with the reforms of the past decade have substantial numbers of scholars been investing substantial time and effort in learning the real needs of the expanding student body and in learning how to meet those needs. A number of seminal documents appeared in the late 1980's: The *NCTM Curriculum and Evaluation Standards for School Mathematics*, the National Research Council report, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, the Sloan Foundation conference proceedings, *Toward a Lean and Lively Calculus*, the National Academy of Sciences conference report, *Calculus for a New Century: A Pump, not a Filter*, and others. A direct outgrowth of this flurry of activity has been a decade of reform efforts at all levels, stimulated in part by the National Science Foundation and other public and private funding agencies.

A key belief supporting the current reform efforts is that virtually everyone can understand mathematics, can achieve at a high level in appropriately designed courses, and can enjoy doing

[1] The full paper is available at the Symposium web site and at http://www.math.duke.edu/ das/essays/delta99/ (at time of publication).

so. Only a minority of the faculty actually believe this, but those who do have found many ways to make it happen. Among the strategies that have been found effective are setting high expectations for students, creating a supportive and cooperative environment, making intelligent use of available tools, posing meaningful and realistic problems, doing hands-on activities in the classroom, guiding discovery learning, and using varied forms of assessment.

Learning from research

At least half a century of research in cognitive psychology has taught us about social constructivism as a model for understanding how learning takes place, as well as the importance of preferred learning styles, stages of mental development, and the malleability of the human mind. Education can be, should be - and often is - a transforming experience.

More recently (in this "Decade of the Brain"), we have had confirming research from neurobiology, including live images of learning brains, which tell us that deep learning is whole-brain activity, involving not just logical processing, but also motion and emotion. A fundamental fact about biology is that our brains have not evolved significantly from those of our hunter-gatherer ancestors, which means that, at birth, we are all much more alike than we are different. We may learn in different ways, but we are all capable of understanding what others know.

The challenge for those who design and deliver educational programs is to use what is known about active engagement of diverse learning styles and backgrounds. Programs that do this lead to greater learning gains, higher satisfaction for both students and teachers, and greater persistence in pursuing educational goals. A recent study by the National Research Council[2] summarizes the research in cognition and brain biology, and a companion volume[3] connects this research with classroom practice. While much of this theoretical base was not in place when the current reform efforts started, it helps to explain why some techniques were found to be more successful than others. And it challenges in very fundamental ways the traditional practices of lecturing, note-taking, mimicry of template problems, competition for scarce grades, and high-stakes, episodic testing - practices still in widespread use in our schools and colleges.

[2] *How People Learn: Brain, Mind, Experience and School*, National Academy Press, 1999.
[3] *How People Learn: Bridging Research and Practice*, National Academy Press, 1999.