Critical National Need: Using virtual classrooms to help U.S. students break the algebra barrier

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> Students who choose not to or are unable to finish algebra 1 before 9th grade—which is needed for them to proceed in high school to geometry, algebra 2, trigonometry, and precalculus—effectively shut themselves out of careers in the sciences.
>
> —Rising Above the Gathering Storm

> …many observers of educational policy see Algebra as a central concern …Among African-American and Hispanic students with mathematics preparation at least through Algebra II, the differences in college graduation rates versus the student population in general are half as large as the differences for students who do not complete Algebra II.
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> —Report of the National Mathematics Advisory Panel

> Employers and college leaders say that graduates from high school need to master higher-level mathematics and communications skills more than ever before. Research reveals that the ticket for student success in work or future learning is taking courses in math beyond Algebra II and advanced courses in English and science.
>
> —Achieve, Inc

As the quotations above illustrate, numerous national reports by government panels and organizations and by independent policy institutes have urged the nation to address its failure to help enough students pass the critical gateway of high school algebra. In some urban areas, half of the students enrolled in Algebra will fail the course. Worse, failing once is a strong predictor of failing again. In some Los Angeles schools, students fail Algebra three, four or five times before dropping out. The problem is especially acute for students who are learning English (who represent a growing proportion of students in the United States) and for students who are members of ethnic groups that have been traditionally under-represented in the sciences.

We have a critical national need to build our human capital in the scientific, engineering and technology professions, all of which require mathematics proficiency. If a student does not pass Algebra I in Grade

8 or 9, the student is no longer on a direct trajectory to participate in science, engineering and technology professions. The problem has been significantly exacerbated because changes in U.S. immigration policies have limited our ability to import mathematically proficient students and workers from other nations.

The nation's teaching workforce does not have sufficient capacity to keep up with the nation's need. Pending retirements in the STEM workforce over the next decade will exacerbate the already serious shortage of well-qualified mathematics teachers. It is estimated that more than half of the teachers now in the classroom will retire within the next five years (Barnes et al., 2007). However, the educational "pipeline" to replace them is running dry; college students with mathematics skills have many more lucrative career options than training to become middle or high school math teachers. For those students that do complete degrees in education, more than half will leave the profession within their first five years in the classroom. One reason is that math teachers can earn significantly more by transferring to other professions. However, another commonly reported reason is that teachers feel frustrated and discouraged at the lack of progress made by their students, in spite of often-heroic teacher effort.

A transformational approach will recognize both the importance of giving students substantial instruction in algebra and the difficulties of increasing the capacity of the teaching corps in a short enough time. We need a transformational approach to ensure that a large percentage of United States students can pass algebra on their first attempt, regardless of the school that they attend and the experience of their mathematics teacher.

We envision the design, development and deployment of technology for instruction that will go far beyond existing drill-and-kill educational software, that will engage students and promote success, and that will provide real-time data about students' progress to teachers and to students themselves, thus making the link between today's learning and future success transparent. The technology will accelerate learning so that students will not spend years trying to pass algebra, only to drop out after repeated failures.

The research and development program we propose is high-risk. Technology-delivered learning opportunities that have been developed to date have not broken through the difficulties of algebra instruction. A 2006 report to Congress by the Institute of Education Sciences concluded that there was no evidence that existing instructional software was helpful for student achievement in math (Dynarski et al., 2007). Thus opportunities for funding from traditional government programs will be difficult to find. The program is also high-risk because educational interventions have a very long history of helping students who are already doing relatively well, while not addressing the needs of those who are far behind (Ceci & Palerno, 2005).

Our vision is transformational in that we argue for technology to improve outcomes for the students who are currently furthest from success, i.e., those whose educational outcomes are most difficult to change. We are not likely to accomplish this without specific government investment that goes beyond traditional sources. The Institute of Education Sciences (the research office of the U.S. Dept. of Education) invests in programs that can improve academic achievement, but requires significant evidence that the program will be effective, so is not likely to invest in high-risk research. The education programs at the National Science Foundation have limited budgets and are currently not likely to provide significant support for technology-related projects with relatively high development costs.

The program we propose has potential for a high reward, because improving students' chances of passing algebra will significantly expand the capacity of our nation's workforce, and will draw into the workforce those students who now are at great risk of not being full participants in our economy. In addition, providing students with new options for truly understanding the concepts of algebra will provide them with tools for more sophisticated comprehension of related topics that require going beyond what can be directly experienced.

We envision virtual lecture halls which combine the capacity for mass instruction one obtains from traditional large lecture theaters with the personal interaction that can be obtained from small class room settings. On the one hand, the intructor can speak over the internet to large numbers of students, unconstrained by limitations of space or time. On the other hand, the instructor can track each student's progress, identify groups of students with similar difficulties, and create short-term chat rooms or long-term online discussion groups for to support collaborative learning. Students can track their own progress towards goals that they set themselves. Current virtual lecture hall systems suffer from a mentality of translating the classroom experience into a web experience. A more visionary approach would build virtual lecture halls from the ground up by studying how students work and play in the virtual universe through interactive websites, social networking, and online worlds.

We envision a community, much like the community of developers of open source software or the community of contributors to Wikipedia, that will provide a conduit for “best practices” discovered in educational research to be made available to students quickly and directly. It will require a major research effort of the best minds to develop and deploy the right combination of search capacity, ease of use, intuitive interface for creating mathematical texts, and social networking capabilities.

We envision multimedia exercises, built from online tools for mindful manipulation of algebraic expressions and equations, that go beyond the current click-through-the-steps approach. Although computer algebra systems such as Maple and Mathematica provide technological tools for performing algebraic manipulations, we are a long way from providing semantically faithful and interactive representations of mathematics that would allow a student and a distant instructor to interact around the mathematics in a simulacrum of the student/tutor relationship. We envision providing teachers with resources that are more effective than textbooks, that are less costly to produce and purchase, that do not weight down students’ backpacks or glaze their eyes, and that are customizable for students with particular characteristics, interests, and language abilities.

Fundamental developments in hardware, software, and education research will be required to bring about the vision we describe here. Developing visionary technology for algebra success will require intense and sustained collaboration between world-class mathematicians, experienced education researchers, computer scientists with the expertise to build the required infrastructure to ensure deployment and evaluation on a large scale, and support from a government willing to take a chance that a new approach will pay off with higher high school graduation rates for its most challenged students.

References

Achieve, Inc. (2008). The Case for Action. Online: http://www.achieve.org/CaseforAction [accessed October 28, 2008].

Barnes, G., Crowe, E., & Schaefer, B. (2007). The costs of teacher turnover in five school districts. Washington DC: National Commission on Teaching and America's Future.

Ceci, S. J., & Palerno, P. B. (2005). The rhetoric and reality of gap-closing: When the "have-nots" gain but the "haves" gain even more. American Psychologist, 60, 149-160.

COSEPUP. (2005). Rising above the gathering storm: Energizing and employing America for a brighter economic future. Washington, DC: National Academy Press.

Dynarski, M., Agodini, R., et al. (2007). Effectiveness of reading and mathematics software products: Findings from the first student cohort. Washington DC: U. S. Dept. of Education, Institute of Education Sciences.

National Mathematics Advisory Panel. (2008). Foundations for Success: The Final Report of the National Mathematics Advisory Panel. Washington, DC: U.S. Department of Education/