Update: Report on Innovations in Developmental Mathematics—Moving Mathematical Graveyards

By Katherine K. Merseth

Every year tens of thousands of students step foot on community college campuses, many for the first time. These students, who may range in age from the teens to 60-plus, and come from a broad array of communities, ethnicities, and language backgrounds, all have one thing in common: hope. They enter these institutions with lofty goals and a fervent expectation that this educative experience they are about to embark upon will fundamentally improve their lives.

Yet, these hopes and dreams often fade and sometimes die within a quarter, a semester, or a year. This is because currently up to 60% of community college students who take the placement exam upon entrance learn they must take at least one developmental education course to build their basic academic skills. High failure rates, increased debt burdens, and a lack of credits on transcripts can accelerate a downward spiral of giving up, checking out, and deciding that "college just isn't for me." Nowhere in the community college curriculum is this failure rate of graver concern than in developmental mathematics courses. Indeed, Carnegie Foundation for the Advancement of Teaching President Anthony S. Bryk has frequently said, "Developmental mathematics courses represent the graveyard of dreams and aspirations."

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This tragic and enormous waste of human potential came to the attention of Bryk shortly after he was named Carnegie's president in 2008. Bryk is a well- regarded educational researcher, statistician, and educator whose work has informed and inspired school reform efforts nationwide. Although he brings the keen discipline of a researcher to complex problems, he is not one to merely diagnose, analyze, and write a report, leaving the "fixing" of the problem to practitioners and those in the trenches. Bryk's approach to research and development puts the day-to-day work of educators at the center of the inquiry. He has said that "good research, good scholarship, broadly defined, can and should stand in a more productive relationship to practice and its efforts to improve."

Though he had no direct experience in the community college sector, Bryk quickly realized that the problem of failure rates in developmental math was alarmingly complex and complicated. Was it a high school preparation problem? A curriculum matter? A faculty concern? A psychosocial issue for many first-generation college students who had no knowledge of what it means to "do college?" Or all of the above, and then some?

Carnegie's Take on the High-Leverage Problem

Bryk gathered a diverse group of partners to advise him as he began this work. He enlisted Bernadine Chuck Fong, president emerita of Foothill College (who later became the initiative's leader); Louis Gomez, professor and director of the University of Pittsburgh's Center for Urban Education; James Stigler, professor of psychology at UCLA, director of the TIMSS video studies and founder of LessonLab Inc.; Uri Treisman, founder and executive director of the Charles A. Dana Center at the University of Texas at Austin; Guadalupe Valdés, a Stanford University professor specializing in language and linguistics; and Cathy Casserly, who came to Carnegie from the William and Flora Hewlett Foundation where she led efforts in Open Educational Resources. As Bryk and his team mulled over this high-leverage problem affecting thousands of students, they consulted community college leaders and members of national education and mathematics groups. They coordinated closely with programs such as Achieving the Dream and the California Community College System's Basic Skills Initiative and reached out to national organizations like the American Association of Community Colleges and American Mathematical Association of Two-Year Colleges.

As a result of these deliberations, Carnegie launched its mathematics pathways initiative in September 2009 to aggressively put an end to the crippling failure rates of developmental math students in community colleges across the country. The goal of the initiative is deceptively simple: to double the proportion of students who in a 1-year course sequence are mathematically prepared to succeed in further academic study.

Yet, the approach to achieve this goal is anything but simple.

The $13 million initiative, funded by six foundations, is building a unique networked community of 27 community colleges and 3 universities to develop two newly designed mathematical pathways across 8 states. These pathways are called Statway™ and Quantway™.

Carnegie is engaging practitioners, researchers, design/developers, institutional leaders, students, and policymakers in ways that will fundamentally challenge and change the character of developmental mathematics. Carnegie's partner in this work is the Dana Center at the University of Texas at Austin, that is developing open access instructional resources organized in an instructional kernel.

Statway™ and Quantway™

Carnegie Foundation's Statistics Pathway, or Statway™, began in December 2009 with the invitation to members of national mathematics and statistics organizations to form the Carnegie Committee on Statistics Learning Outcomes (CCSLO). This committee, comprised of prominent university and community college faculty, was charged with developing the learning outcomes for Statway™. The result of these deliberations as well as further study resulted in the design of a pathway focusing on college–level statistics melded with necessary developmental mathematics topics. The pathway is designed for non–STEM (science, technology, engineering, and mathematics) students who desire a college–level statistics course. Essential mathematics concepts are introduced in the context of statistics and integrated throughout. The sequence will meet the requirements of various academic programs and careers. Thus, students who successfully complete the sequence receive credit for a college–level, transferable statistics course.

The overarching goal of the Statway™ experience is for students to develop better problem–solving skills and be more confident and competent in quantitative situations. Students completing the Statway™ pathway will understand that data analysis is a process that begins with the formulation of a question which can be addressed with appropriate data, followed by the development of a thoughtful plan for identifying, collecting, and analyzing the necessary data. Students will know how data can be displayed and summarized in informative ways, and they will understand how to use data to draw conclusions in the presence of uncertainty.

Quantway™, the second pathway, began in early 2010 with the work of the American Mathematical Association of Two-Year Colleges (AMATYC). Building on this initial effort, in July 2010, the Carnegie Foundation invited eight colleges in three states to engage in the development of Quantway™. However, as work began with faculty, it became apparent that the original AMATYC concept of a 1-semester Mathematical Literacy for College Students (MLCS) elementary and intermediate algebra course should be expanded to increase emphasis on quantitative literacy.

Over the last two 2 decades there has been a growing recognition among the mathematics community that the modern world demands an ability to use mathematics in ways that both build upon and transcend the traditional mathematical topics of algebra, geometry, and statistics. This ability has been variously labeled as quantitative literacy, quantitative reasoning, numeracy, and mathematics in use. This diverse professional conversation began to converge with official groups such as the Mathematical Association of America's Quantitative Literacy Subcommittee of the Committee on the Undergraduate Program in Mathematics in 1996. Since that time, other professional organizations have officially embraced quantitative literacy as a field worthy of study in higher education. To date, numerous national and international organizations and groups have published statements defining and supporting quantitative literacy, including the AMAYTC, Mathematical Association of America, Association of American Colleges and Universities, National Academy of Sciences, National Numeracy Network, Partnership for 21st Century Skills, National Council on Education and the Disciplines, and Programme for International Student Assessment (PISA).

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In Quantway™, students will focus on understanding and applying the mathematical concepts needed to facilitate their quantitative literacy rather than memorizing seemingly disconnected processes and procedures, as is often the case now. Quantway™ represents a non-STEM pathway in which students use numerical reasoning for decision making, argumentation, and sense making about real-world questions and problems in contexts of personal, social, and global importance. Quantway™ will require that students use mathematics and numerical reasoning to make sense of the world around them.

As college faculty and Carnegie Foundation staff working with partners at the Dana Center began to develop this 1-semester quantitative reasoning course, it became evident that a follow-up course would also be needed. The National Survey of America's College Students (Baer, Cook, & Bald, 2006) assesses literacy skills, including quantitative literacy, of college students at the end of their program of study in two-year and four-year institutions. The study found that, of the three types of literacy assessed, students struggled most with quantitative literacy. Despite this and other evidence that the current courses are not preparing students adequately for life in a society saturated with quantitative information, there is currently no quantitative literacy curriculum with strong legitimacy that can be implemented in a variety of different institutions. Carnegie Quantway™ developers now think that the field needs such a curriculum, not to standardize quantitative literacy courses but rather to set a standard for existing courses to be evaluated against and to provide an option for the vast majority of colleges that have yet to establish meaningful and rigorous quantitative literacy courses.

Similarities between Statway™ and Quantway™

Both Statway™ and Quantway™ target students who are at grave risk of failure in mathematics courses at the community college level. These students may have weak K-12 preparation, face language and special education challenges, or fundamentally believe that they are destined to not do well in the subject. In the current configuration of developmental math courses, these students often find themselves struggling unsuccessfully to complete multiple developmental mathematics courses that mirror their earlier failed mathematics experiences. In addition, students see the current collection of developmental math courses as having no relevance to their aspirations or the world around them. The cumulative effect of these barriers and subsequent failures fundamentally limit the potential college majors and future career options of these students. Both Statway™ and Quantway™ seek to interrupt this pernicious and disheartening experience for too many students.

Another commonality between Statway™ and Quantway™ is that they both employ materials and teaching approaches that deeply engage students. These pathways will not resemble the arithmetic and algebra classes that the students have taken before and are now repeating in community college. Both courses intend to use new approaches, topics, and contexts so that students can learn to think and reason quantitatively, unencumbered by memories of past failures. Therefore, statistics and concepts of quantitative reasoning will be in the foreground with mathematics mainly as a subplot that reinforces and supports the learning of these topics. The developmental mathematics concepts required to support statistical and quantitative understanding will be integrated throughout.

Outcomes

Statway™ students will enroll in a year-long sequence which results in credit for a college-level statistics class. At the conclusion of this sequence, Statway™ students should have proficiency in developmental math concepts and be able to move forward in an academic program for credit. Students completing the Quantway™ 1-semester course will have different options. For example, after completing Quantway™ students will be prepared to take a Quantitative Reasoning or non-STEM college-level course already available at the college or to enter a specific vocational program requiring mastery of developmental math concepts.

Statway™ and Quantway Pathway Components

Several components make up both Statway™ and Quantway™. Each provides detailed lessons that include student pages and instructor guides that embody a learning philosophy comprised of elements of productive struggle, explicit connections, and deliberate practice. There are out-of-class (homework) activities and assessments for end-of-unit and end-of-course evaluations. In Statway™ student materials comprise over 80 individual lessons gathered into 12 modules. Similarly, Quantway™ materials include student lessons (approximately 36 lessons in 4 modules), instructor guides, out-of-class activities, and assessments. All materials will be open source and made available to participating colleges.

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In addition, several strategic components of the materials lend a distinctive look and feel to Statway™ and Quantway™. These include special attention to issues of student engagement and motivation, innovative faculty development mechanisms to support faculty in the teaching of these materials, and language and literacy issues.

Productive Persistence

Many students in developmental mathematics classes are first-generation college attendees who can find themselves in a complex and confusing maze. To address the challenges of navigating college and mathematics, Quantway™ and Statway™ will integrate content commonly referred to as "college knowledge." Both pathway designs will attend to what is known about effective student support practices, building faculty-student relationships, increasing and diversifying communication between students and mathematics faculty, and making access to college support services more visible and user-friendly.

At least four factors lead to disengagement and lack of motivation to persevere in math classes for many developmental students. These include the reality that the students find the current developmental math course content irrelevant, dull, and boring. Second, students may lack the necessary skills and habits of mind required for college success. For example, students may not realize that attendance in class is usually helpful to one's success or be aware that asking for help is not a sign of weakness. Third, students may not perceive of themselves as math learners, so there is a defeatist attitude operating even before the first class begins. Finally, many developmental math students have weak ties to peers and faculty—resources that could be helpful to them as they work through the material of the courses.

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A useful umbrella term for these elements of motivation and engagement is "productive persistence," defined as the set of relevant student engagement behaviors (attendance, working hard, working smart) along with skills and mindsets that support student success. Many of these ideas come from the research of social psychologists. For example, a recent paper on "academic tenacity" by Dweck, Cohen, and Walton (2011) of Stanford University describes productive persistence:

> Students are engaged in learning, view effort positively, and are able and willing to forego immediate pleasures for the sake of schoolwork. For example, they seek challenging tasks that will help them learn new things, rather than tasks well within their comfort zone where they do not have to work hard or risk failure. Next, difficulty (confusion, setbacks, failures) does not derail them. They see a setback as an opportunity for learning or a problem to be solved rather than as a humiliation, a condemnation of their ability, a symbol of future failures, or a confirmation of their identity as a non-student. This is true at the level of a given task and at the level of their studies in general—they know how to remain engaged over the long haul and how to deploy new strategies for moving forward effectively. (p. 5)

Keeping these factors in mind, Carnegie's math pathways will include specific activities, support systems, and pedagogical approaches designed to encourage and build these skills and mindsets in order to increase success in the pathway courses. Although the initial focus will be on retaining students in the pathway courses, what students learn in their Quantway™ and Statway™ classes will support their overall ability to navigate college, employ self-efficacy, augment motivation, and increase persistence.

Professional Development

Efforts to improve the developmental mathematics experience for community college students rest on a seemingly obvious, yet sometimes ignored, maxim: Providing new curricular materials alone without concomitant supporting structures for faculty using these new materials is a short-sighted endeavor. Indeed, new materials taught in old ways without recognition of the learner typically produce a mélange that neither satisfies students, faculty, or curriculum reformers. David Cohen (1990), Carnegie Foundation Board member, documents the challenges of teaching new materials:

> After all, the teachers and students who try to carry out such change are historical beings. They cannot simply shed their old ideas and practices like a shabby coat, and slip on something new…As they reach out to embrace or invent a new instruction, they reach out with their old professional selves, including all the ideas and practices comprised therein. The past is their path to the future. (p. 323)

Thus, supporting faculty members as they implement Statway™ and Quantway™ is an essential component of the initiative and will require a multifaceted, multiyear, multi-institutional approach. Such an approach touches on many elements within the college campus community, including institutional and administrative policies; the creation of new partnerships; and the direct engagement of faculty in new forms of learning, teaching, and working.

Several exciting approaches to support faculty as they participate in these new pathways are under consideration by Carnegie staff, and some have been slated for use in a Summer Institute for faculty in Palo Alto, California, in July 2011. The categories of these activities focus on various areas including classroom materials, pedagogical practices, content support in statistics and developmental mathematics, and future institutional support. For example, each student lesson will have an Instructor's Guide that not only suggests pedagogical approaches for the specific content but also may include additional resources, extension ideas, and alternative data sets. Further, as part of the initiative, faculty will contribute additional teaching suggestions and ideas as the materials are piloted; these will be added to the Instructor's Guides.

Instructional practice support is an exciting area for faculty development. One innovative idea is the production of multiple videos featuring community college faculty teaching Statway™ and Quantway™ lessons. These videos will form a video library residing on the web that will grow with contributions from faculty members as they work with the materials. Student work, interviews with the faculty member, and supporting materials from research will supplement the videos. Another activity is to develop a pedagogical "tool kit" with examples for faculty regarding topics such as leading classroom discussions, dealing with wrong answers, addressing conceptual confusions known to exist for students, questioning strategies, and engaging quiet students and Limited English Proficient learners. A third pedagogical tool will be a collection of case studies depicting challenging moments in Statway™ and Quantway™ classrooms. These anonymous cases will be useful for professional development conversations and sharing sessions among faculty at the individual colleges. Finally, an observation tool designed with Statway™ and Quantway™ lessons in mind is under development for use by colleagues as they visit each other's classrooms.

For issues related to mathematics and statistic content knowledge, the initiative is planning a series of webinars on topics known to be challenging to teach as well as an interactive Carnegie helpdesk or blog where faculty can ask questions of the content as well as the materials and share suggestions and ideas.

Finally, the Carnegie Foundation is considering the creation of a certification program for Statway™ and Quantway™ instructors. Such a program would certify that the faculty member is familiar with the materials, the instructional philosophy and approach, the assessments, and the out-of-class materials and has a commitment to teach these courses and share their experiences with the Carnegie Foundation and members of pathways initiative.

Language

Carnegie began the pathways work recognizing the need to be aware of the role of language limitations in the study of mathematics. Under the guidance of Guadalupe Valdés, the Foundation looked at instructional delivery systems (both face-to-face and online), text materials, classroom activities, and assessment systems. There was little information collected on students' language characteristics and on the relationship between these characteristics and students' success and/or failure in particular academic departments. It seemed an obvious missing piece of the student success dynamic.

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Because of the importance of language in the learning of mathematics (or any subject for that matter), the design of Statway™ and Quantway™ student materials, out-of-class exercises, and assessments will seek to minimize language barriers. Most of the time, difficult language has less to do with mathematical vocabulary than the way that texts are written. Key problems in traditional texts include: wordiness (*it is my intention* versus *I intend to*), long and unnecessarily complex sentences with many dependent clauses, use of dummy subjects (*it appears that students drink too much* versus *students drink too much*), and other similarly avoidable and unnecessarily complicated expressions.

Efforts to avoid these and other confusing and unnecessary language barriers in the pathway materials will be accomplished in several ways. First, the initiative will work to remove unnecessary complexities within the texts themselves. For example, there is no reason to write complicated, dense paragraphs or to use colloquialisms (e.g., piece of cake) that may be unfamiliar to students who come from non-English backgrounds. Second, initiative leaders are designing writing guidelines specifically for Statway™ and Quantway™ and lessons that build on a set of guidelines based on the initial work of the federal government to provide clear and readable texts in the military, government, and legal arenas. Third, the Statway™ and Quantway™ materials will deliberately model good writing in mathematics so that students develop a sense of what an effective explanation or a proper justification in a mathematical argument looks like. Finally, the initiative will ensure that the content and the focus of the instruction are clear.

Network Improvement Community

How will all of this work be coordinated and how will it be shared among community college constituents? Carnegie is catalyzing and supporting the growth of a Networked Improvement Community (NIC) that involves practitioners, researchers, designers/developers, institutional leaders, students, and policymakers in ways that will fundamentally challenge and change the character of developmental mathematics. The notion of a NIC was first introduced by Englebart when he defined an "improvement community" as any group involved in a collective pursuit to improve a given capability. Further he suggested that an "improvement community that puts special attention on how it can be dramatically more effective at solving important problems, boosting its collective IQ by employing better and better tools and practices in innovative ways, is a *networked improvement community* (NIC)" (Englebart, 2004).

Another critical component of the initiative is the development and promotion of a research and development (R&D) infrastructure termed improvement research. This approach will allow the initiative to cull and synthesize the best of what is known from scholarship and practice, to rapidly develop and test prospective improvements, to deploy what is learned about what works in classrooms, and to add knowledge to continuously improve the performance of the system. This common knowledge development and management system guides network activity and ensures that whatever is developed and learned becomes a resource to others as these efforts grow. All of the institutions working on the developmental math challenge become part of what is called a Collaboratory (defined as a "center without walls") in which researchers work without regard to physical location, interacting with colleagues through a networked community. This networked organizational form includes social processes, collaboration techniques, and formal and informal communication (Cogburn, 2003; Wulf, 1989).

Bryk and his colleagues believe that this approach will not only produce powerful solutions to the challenges of developmental mathematics but will also offer a prototype of a new infrastructure for research and development. Carnegie's aim is to support system reforms that will simultaneously impact community college instruction, the field of developmental mathematics, and the process of continuous educational improvement.

Conclusion

In the United States today, awareness exists from the Oval Office to family living rooms that education is critical to the public good and is the engine that drives individual upward mobility. Expectations are especially high that community colleges—those institutions that traditionally have been and still are thought of as the gateway to postsecondary education—could be the key to a better life and greater financial security for millions of Americans.

However, too many students find developmental mathematics to be an insurmountable impediment to their academic success. As Tony Bryk has said, those courses are where aspirations go to die. The goal of Carnegie's pathways is to reverse the alarmingly high student failure rate in the traditional developmental math sequence. Though it is reputed to be notoriously hard to move graveyards, the Carnegie Foundation has every intention to not only move but also remove this mathematical graveyard.

References

Baer, J., Cook, A., & Bald, S. (2006). *National survey of America's college students*. Washington, DC: American Institutes for Research.

Cogburn, D. (2003). HCI in the so-called developing world: What's in it for everyone. *Interactions, 10*(2), 80-87, New York, NY: ACM Press.

Cohen, D. (1990). A revolution in one classroom: The case of Mrs. Oublier. *Educational Evaluation and Policy Analysis, 12*(3), 311-329.

Dweck, C., Cohen, G., & Walton, G. (2011). *Academic tenacity*. An unpublished white paper prepared for the Gates Foundation.

Englebart, D. (2004). *Augmenting society's collective IQ*. Remarks made in Hypertext 2004 Keynote Speech.

Wulf, W. (1989, March). The national collaboratory. In *Towards a national collaboratory*. Unpublished report of a National Science Foundation invitational workshop. New York, NY: Rockefeller University.

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NCAT's Emporium Model

An update on the National Center for Academic Transformation's (NCAT) course redesign for developmental mathematics using the emporium model is planned for inclusion in a future issue of the *Journal of Developmental Education* (JDE). Space limitations did not permit including the full NCAT report on this topic submitted to the *JDE* for this theme issue in developmental mathematics.

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