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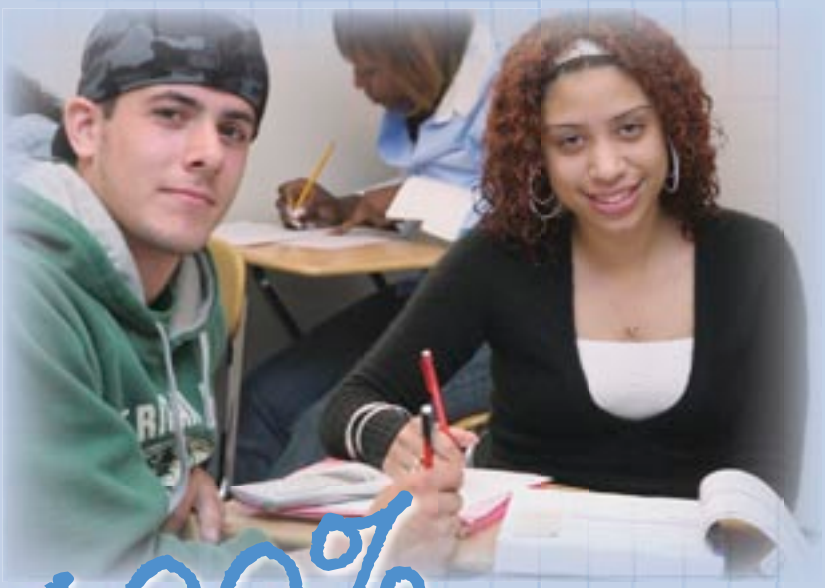

100% MATH INITIATIVE

Building a Foundation for Student Success in Developmental Mathematics

A FIPSE Funded Project

Fund for the Improvement of Post Secondary Education

Cover design, report layout and photography by Jane Albert.
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Building a Foundation for Student Success

in Developmental Mathematics

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Building a Foundation for Student Success in Developmental Mathematics

Created by the collaboration efforts of Developmental Mathematics Professionals within the Community College System of Massachusetts

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Massachusetts Community Colleges

Building a Foundation for Student Success in Developmental Mathematics

Report and recommendations of the 100% Math Initiative:

A statewide effort to improve the quality of developmental mathematics instruction at Massachusetts community colleges.

The 100% Math Initiative was supported by the Fund for the Improvement of Postsecondary Education (FIPSE) of the U.S. Department of Education. (Grant # P116B020767)

Preface

By Hunter R. Boylan, Ph.D.

Professor and Director
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Developmental mathematics is the developmental course entering community college students are most likely to be required to take. But it also has the dubious distinction of being the one they are most likely to fail. Nationally, approximately one out of every three students entering a community college will have to take developmental mathematics (Boylan & Saxon, 1998). Of those students taking developmental mathematics, one out of every three will fail the course on their first attempt. By comparison, less than one out of four students fail developmental English or reading on their first attempt (Gerlaugh, Boylan, & Rodriguez, 2006).

Furthermore, many students must retake developmental mathematics two or three times before they finally pass the course. Unfortunately, stifled by failure, many other students never bother retaking developmental mathematics. They just quietly drop out of college.

At the same time, developmental mathematics serves as a gateway course for college transfer as well as for nearly all vocational and technical credentials. College Algebra is an essential course for those seeking to transfer to a four-year institution, yet many students in college transfer programs will have to take and pass developmental mathematics before they can enroll in College Algebra. For those seeking vocational or technical certification, developmental mathematics is often a requirement that must be met in order to achieve certification. Developmental mathematics, therefore, can represent a barrier to the attainment of many students' educational aspirations.

As noted in this report, the vast majority of developmental mathematics courses are taught by part-time adjunct faculty. Although there is no evidence that adjunct faculty are any better or worse instructors than full-time faculty, the low success rate in developmental mathematics courses is probably exacerbated by the fact that there are more part-time adjunct instructors teaching developmental mathematics than any other developmental course. Typically, part-time faculty have

less time available outside of class to assist students individually, provide advice on study skills, or provide other student support. Yet developmental mathematics is the one subject in which students are likely to need the most individual help, advice, and support from faculty. Furthermore, although adjunct faculty teach the most developmental mathematics courses, they are frequently the faculty least likely to have access to the professional development activities or other departmental activities that might be of greatest benefit to them.

It should be obvious that we must find ways to do a better job in developmental mathematics. We cannot continue to simply fail large numbers of students in developmental mathematics and then ask them to retake the same course as their only alternative.

The following report from the 100% Math Initiative represents a welcome effort to address some of the key issues in developmental mathematics as well as a serious attempt to find ways of improving student performance in developmental mathematics. This report places the responsibility for improving developmental mathematics outcomes squarely on those who teach developmental mathematics and those who lead institutions where it is taught. It also recognizes that improving developmental mathematics is ultimately an institution wide and even a statewide responsibility.

The recommendations included here are comprehensive, timely, and well-validated by research. If these recommendations are taken seriously and implemented properly, they will improve student performance in developmental mathematics.

This report is also particularly important because it is the first in-depth discussion of developmental mathematics that acknowledges one of the most important characteristics of successful developmental education – what goes on between instructors and students in individual classrooms.

Ultimately, developmental courses are designed to change students' academic attitudes and behavior. In order for these changes in student behavior to occur in a consistent, productive, and systematic manner, developmental education faculty as well as the institutions in which they work will have to change their behaviors. Educators who read this report are encouraged to bear in mind that often the least costly but most effective form of innovation is to change our own behaviors.

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Gerlaugh, K., Boylan, H.R., Rodriguez, L. (2006, In press). National study II: Baseline data for community colleges. *Research in Developmental Education*

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Executive Summary

In 2002, the Massachusetts Community Colleges created the 100% Math Initiative through a grant from the Fund for the Improvement of Post Secondary Education (FIPSE), under the auspices of the U.S. Department of Education. This three-year project proposed to reduce the barriers that block students' success in developmental mathematics by assessing and resolving issues at the classroom, campus, and system-wide levels. In particular, the 100% Math Initiative focused on developing an improved set of approaches, structures, and systems driven by specific student and faculty needs that would foster and support the types of critical interactions between faculty and student that are the bedrock of success among developmental mathematics students.

In many ways, the 100% Math Initiative has been a logical continuation of the process that lead to *Access and Quality: Improving the Performance of Massachusetts Community College Developmental Education Programs,* published by the Massachusetts Community College Developmental Education Committee in July 1989. It represents the ongoing efforts of the community college educational leadership to improving the quality of developmental education and giving all students the educational services and support they need to succeed.

During three years of research, training, and classroom experience, the project explored many facets of developmental mathematics and established recommendations to improve both the quality of instruction and the institutional supports behind it. This report presents guidelines and specific recommendations for improving the quality and effectiveness of developmental mathematics education. Given the variety of approaches and cultures that exist at the various Massachusetts community colleges, implementation of these recommendations may vary with the needs and circumstances of each campus. These guidelines, along with a statewide structure through which the community colleges can share their successes and best practices, will foster a culture of continuous improvement in developmental mathematics instruction throughout the state.

The 100% Math Initiative brought together educators from all 15 Massachusetts community colleges to think through these issues and make practical recommendations for improvement at the classroom, campus, and system levels. The 100% Math Initiative's recommendations fall into several categories. They are summarized here as a way of looking at the broad picture and understanding how the pieces fit together.

Instructional Strategies

First, developmental mathematics instructors need to understand, be familiar with and implement the range of instructional strategies and classroom structures that are required to effectively teach today's developmental mathematics students. They must be sensitive to their students' differing learning styles by varying their classroom methodologies, actively involving students in the education process and adapting their own teaching techniques based on the material being taught. Teachers should include real world application of the materials presented in their classes and emphasize the importance of homework completion and quality, ultimately using an electronic or online homework system as an aid. Instructors should teach students basic study skills including note-taking, test-taking, working in groups and how to use homework and self-study effectively. Finally they must receive training and professional development from their campuses to maximize their effectiveness with this population.

Campus Support

It is recommended that community colleges create and support the position of campus developmental mathematics coordinator. This position would oversee and coordinate curriculum development, instructor professional development, and linkages with other campus units that can provide support to developmental mathematics students. In addition, colleges should develop and use an orientation and handbook for developmental mathematics instructors and provide training and professional development for instructors. They should also strongly support mathematics centers that provide tutoring, reference materials, online help, and supplemental instruction. They should develop clear course entrance, exit, and completion requirements and offer student orientation to developmental mathematics. Campus mathematics or developmental education departments should review the scope and sequence of their developmental mathematics program, and move toward the implementation of a three-course sequence: Foundations of Mathematics, Foundations of Algebra I, and Foundations of Algebra II. They should provide student support services including advising specifically geared to developmental education, remedial tutoring, homework help, and test preparation. Finally, community colleges should consider expanding the contact time for developmental mathematics to accommodate the integration of study skills and general process skills, as well as other aspects of quality instruction for this population.

Systemic Advocacy and Organization

The 100% Math Initiative recommends the creation of a statewide Developmental Mathematics Leadership Group (DMLG) to coordinate the implementation of these recommendations. The DMLG's goal will be to significantly increase student success in developmental mathematics system-wide. To do so, the DMLG will be the developmental mathematics community's center of research, data gathering, communication, and advocacy to promote reform across the system. The DMLG will research, develop, recommend, disseminate, and assess instructional content, course delivery methods, and ongoing faculty development. It will advocate for increased funding, more full-time faculty, the role of online instruction in developmental mathematics, and revisiting and updating developmental mathematics assessment and placement policies. Collecting data on the effectiveness of various developmental mathematics improvement strategies is one of the key recommendations of the 100% Math Initiative.

These recommendations represent a comprehensive approach that will enable Massachusetts community college instructors and administrators to make a significant contribution to increasing the success rates of students taking developmental mathematics, and to support and sustain those gains into the future.

The Council of Presidents for the fifteen Massachusetts Community Colleges has unanimously endorsed the recommendations contained within this report.

Introduction

For more than ten years, Massachusetts' fifteen community colleges have been focusing substantial time, money, and resources on improving developmental education. These efforts correlate with a national trend. The challenges facing developmental education programs, including large numbers of students, under-prepared faculty (often adjunct faculty), and low success rates, are consistent throughout the country.

Many of these issues are particularly acute in developmental mathematics. Today, there are more than two million enrollments in developmental mathematics (basic arithmetic and basic and intermediate algebra) in community colleges nationally. Developmental mathematics is the single largest program in community colleges nationwide, enrolling more than 15% of all students, with failure rates reaching as high as 50%.

Educators and educational administrators must tackle these difficult pedagogic and institutional issues head-on. If not, many students will be needlessly limited in progressing through their education and careers. Developmental mathematics cannot continue to be an impenetrable barrier to a college education for so many students, blocking them from obtaining the skills for and opportunities of 21st century jobs. We must eliminate this major contributor to student frustration, lack of confidence, and high dropout rates in community colleges.

In 2002, the Massachusetts Community Colleges created the 100% Math Initiative through a grant from the Fund for the Improvement of Post Secondary Education (FIPSE), under the auspices of the U.S. Department of Education. This three-year project proposed to reduce the barriers that block students' success in developmental mathematics by assessing and resolving issues at the classroom, campus, and system-wide levels. In particular, the 100% Math Initiative focused on developing an improved set of approaches, structures, and systems driven by specific student and faculty needs that would foster and support the types of critical interactions between faculty and student that are the bedrock of success among developmental mathematics students.

During three years of research, training, and classroom experience, the project explored many facets of developmental mathematics and established recommendations to improve both the quality of instruction and the institutional supports behind it. The project considered issues including student placement, the nature of instruction itself, the qualities that exemplary teachers bring to the instructional setting, the professional development needs of a growing adjunct faculty and the benefits that statewide communication and coordination would provide. This work resulted in the recommendations that are discussed in this report. This comprehensive approach will enable Massachusetts' community college instructors and administrators to make a significant contribution to increasing the success rates of students taking developmental mathematics.

This report summarizes the three-year 100% Math Initiative and includes recommendations that have emerged from practice-based experience in Massachusetts, as well as existing models from around the country. (The Massachusetts experience is discussed in detail, with references to other models as appropriate). This report presents guidelines and specific recommendations for improving the quality and effectiveness of developmental mathematics education. Given the variety of approaches and cultures that exist at the various Massachusetts community colleges, implementation of these recommendations may vary with the needs and circumstances of each campus. These guidelines, along with a statewide structure through which the community colleges can share their successes and best practices, will foster a culture of continuous improvement in developmental mathematics instruction throughout the state. This report can serve as a reference and source book for developmental mathematics educators in Massachusetts and beyond.

In many ways, the 100% Math Initiative has been a logical continuation of the process that lead to *Access and Quality: Improving the Performance of Massachusetts Community College Developmental Education Programs*, published by the Massachusetts Community College Developmental Education Committee in July 1989. That report provided assessment criteria in developmental

reading, writing, and mathematics, and offered a clear set of frameworks for the assessment of all students, and for the instruction, advisement, and support of those who need extra academic help. *Access and Quality* resulted in an ongoing statewide task force to review issues in developmental education. The 100% Math Initiative became the critical mathematics-specific initiative that grew out of that effort.

The recommendations in this report result from three years of congenial and enthusiastic cooperation among representatives of the state's fifteen community colleges, and they are owed a debt of gratitude for their commitment and hard work. Each college sent a group leader to receive training in certain technology teaching and curriculum development tools, to conduct research, and to compare experiences and best practices related to the various aspects of high quality developmental mathematics teaching. The recommendations presented in this report represent their best understanding of how developmental mathematics can be improved so that a significantly higher percentage of students gain the knowledge and skills they need to move on successfully in their academic careers.

(Note: Recommendations are presented throughout this report. A brief summary of all the recommendations is attached as Appendix A.)

The Current State of Developmental Mathematics

Historical Background

Developmental education has been part of American higher education since colonial days. In the 17th century, Harvard College provided tutors in Greek and Latin for selected under-prepared students. Land-grant colleges established in the middle of the 18th century offered preparatory programs for students weak in reading, writing, and arithmetic. The University of Wisconsin offered the first developmental program in the "three Rs" in 1849 (Breneman and Haalow, 1998; Payne and Lyman, 1998). By 1894, more than 40% of college freshmen enrolled in pre-collegiate programs (Ignash, 1997, Winter).

Little has changed. A 1995 survey by the National Center for Education Statistics found that 78% of higher education institutions that enrolled freshmen offered at least one developmental reading, writing, or mathematics course. One hundred percent of public two-year colleges and 94% of postsecondary institutions with high minority enrollments offered developmental courses. Twenty-nine percent of first-time freshmen enrolled in at least one of these courses (U.S. Department of Education, 1996).

As higher education enrollments grow, the numbers of under-prepared students grow proportionately. Their circumstances vary. Some never had the opportunity to acquire academic skills. Others were simply discouraged from developing their abilities. Many attended inadequate schools and came from deprived circumstances, while others received diplomas and entered the workforce only to find they needed to refresh their skills in order to advance their careers (McCabe and Day, October, 1997). Many of these circumstances create a level of "math anxiety" or lack of confidence that has a detrimental effect on their performance in mathematics classes.

The Institute for Higher Education Policy concludes that "the need to help under-prepared students has been embedded in the very fabric of the nation's higher education system for well over three centuries. What we now call remedial education has not been caused by current admissions standards, the availability of federal financial aid, or any of a number of other concerns that have been raised in the recent policy discussions. As higher education continues to educate an ever-growing proportion of the population, there is every reason to conclude that remediation will continue to be a core function of colleges and universities" (The Institute for Higher Education Policy, 1998).

The Place of Developmental Mathematics in Postsecondary Education

"The primary task of developmental education professionals is to fine-tune the balance of challenges and supports in a variety of cognitive and non-cognitive areas. The challenges should extend the reach but not exceed the grasp of students. The supports should be affirmative, yet demanding. The end product of this endeavor is promoting the holistic development of our students and, thereby, help them attain their full potential. That's why we call it developmental education."

– *Adjunct Faculty Instructional Notebook, San Jacinto College*

Solid mathematics skills are essential for all students entering the U.S. job market, even for those not planning to pursue math, science, or technology-related careers. According to researcher Sheila Tobias, mathematics ability is a gateway to many occupations that are not necessarily math-related. *The Dictionary of Occupational Titles*, published regularly by the U.S. Department of Labor, codes occupations by one of six mathematics-competence levels, from arithmetic (levels 1 and 2) through intermediate algebra and geometry (level 3) to algebra, calculus, and statistics (level 5), and higher competence in these subjects (level 6). Those at levels 1 and 2 are constrained from gaining employment in whole families of occupations, making competence in mathematics a significant vocational filter (Tobias, 1993). In addition, mathematics jargon is imbedded in our language. Tobias claims that mathematics expressions like "slope of the curve," "zero sum," and "normal distribution" have become part of the basic vocabulary of fields as diverse as business, politics, library management, health care, and social work. Understanding the mathematics behind these expressions provides a way of conceptualizing relationships that would otherwise be unavailable (Tobias, 1987).

"Today's economy demands more than rote skills. It demands analytic power, disciplined thinking, and creative imagination. Mastery of math & science concepts is the foundation on which to build the skills necessary for success in today's changing economy."

- *The Formula for Success: A Business Leader's Guide to Supporting Math & Science Achievement*

Unfortunately, American students are often not well prepared in mathematics during their K-12 educations. In 1995, the Third International Mathematics and Science Study (TIMSS) concluded that eighth grade students in the U.S. performed poorly when compared to their counterparts in other countries (TIMSS, 2001). The results of the follow-up study four years later, the TIMSS-R, showed little change in that performance (TIMSS, 1999), and current data demonstrates these trends are continuing.

As a result, many students spend time trying to gain these mathematics skills once they enter college. In 1995, the American Mathematical Association of Two-Year Colleges (AMATYC) published *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus*, which established standards for introductory mathematics courses. That study reflected the results of an earlier survey indicating that "over 80% of the students studying mathematics in two-year college mathematics

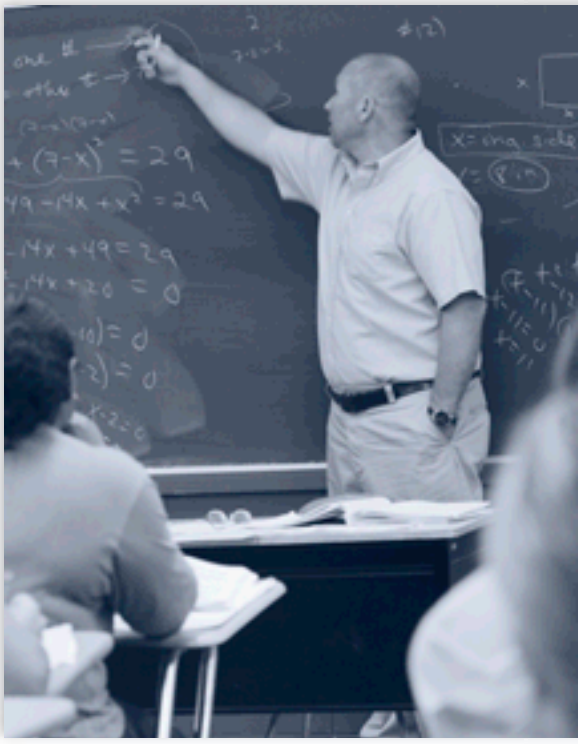
departments are in these introductory courses," e.g., developmental, pre-calculus, technical mathematics, liberal arts, mathematics for secondary teachers (Albers, D., Loftsgaarden, D., Rung D., & Wattloms, A., 1992).

The Current Effectiveness of Developmental Mathematics Programs

It has been difficult to determine the effectiveness of developmental mathematics education because most states and colleges do not have exit standards for developmental courses and do not perform systematic evaluation of their programs (Crowe, 1998; Weissman, Bulakowski, and Jumisko, 1997). Recently, two economists were able to make a valid comparison between students of similar backgrounds, some who take developmental mathematics classes and some who do not (Bettinger and Long, May, 2005). They found that students who took developmental courses in mathematics were 9.9% more likely to complete a bachelor's degree within four years than were students with similar high school preparation who did not take such courses. Moreover, the impact of developmental mathematics appears to increase as the student's American College Test (ACT) scores increase across all of the outcomes. Developmental mathematics also appears to increase the likelihood of degree completion among students intending to major in math-related fields, though it slightly reduces the likelihood of majoring in such a field.

Characteristics of Developmental Mathematics Students and Faculty

While the two million developmental mathematics students nationally represent a wide range of backgrounds and competencies, there are a number of noteworthy common characteristics. Many of the students are racial and ethnic minorities, come from lower-income school systems, or are "first in family" college students. Often, they are academically "unaffiliated" – they have not yet chosen a career path and are therefore unclear about what competencies they will need in order to succeed. These "unaffiliated" students often feel they are on their own, both at home and on campus, and therefore may need additional support for classroom success beyond what their developmental mathematics classes can offer.



The developmental mathematics classes these students enter also share a key characteristic: up to 85% are taught by adjunct faculty rather than full-time professors, which can put some students at a disadvantage. Adjunct faculty offer several advantages to community colleges. They have content expertise in mathematics, their part-time status offers greater flexibility in scheduling classes, and their skills can often be matched to the level of the classroom. On the other hand, adjunct faculty can present challenges to maintaining high quality teaching. Their pedagogical proficiency varies widely and they typically have high turnover rates. In addition, they are not engaged in the college community at the same level as full-time faculty, i.e. they come to campus only to teach, they are not involved in interdepartmental committees, they usually do not engage in professional development efforts, and, in many cases, they do not maintain office hours. These differences give rise to a concern that an over-reliance on adjunct faculty makes a significant difference in the quality of developmental mathematics teaching, especially for students who may need extra support. The system-wide dependence on adjunct faculty makes it difficult to implement the systemic changes necessary to improve the quality and effectiveness of developmental mathematics instruction.

Design and Implementation of the 100% Math Initiative

The goal of the 100% Math Initiative was two-fold: to spark changes in instructional practice that would foster improved student retention and performance, and to similarly inspire changes at the campus and system levels to promote and sustain that improved instructional practice. These efforts are intended to be mutually re-enforcing: systemic and classroom improvements together can enable the changes that propel students toward success.

The 100% Math Initiative is a continuation of the process that led to the *Access and Quality* report (described in the Introduction) and represents a sustained commitment on the part of the Massachusetts community colleges to improve the quality of developmental education. *Access and Quality* addressed developmental education in general, while the 100% Math Initiative focused specifically on developmental mathematics, but their goals are similar. Since the *Access and Quality* report was published in 1998, a number of other events and initiatives, such as the Massachusetts Statewide Teaching and Learning Conference, have given these issues a higher profile among community college instructors and administrators in Massachusetts. With this kind of attention focused on the complex issues of developmental education, this was an opportune time to initiate significant system-wide improvement efforts specific to the issues that impact the effectiveness of developmental mathematics programs.

In recent years, there have been a number of attempts to develop and disseminate improved developmental mathematics programs at the Massachusetts community colleges. Few have shown consistent success, facing problems including limited faculty participation and buy-in, the dissipation of initial energy and drive in the context of competing priorities, the challenges related to training adjunct faculty in new instructional methodologies, and the challenge of restructuring instructional environments to take advantage of innovative instructional approaches. Therefore, the 100% Math Initiative developed a vehicle – The Developmental Mathematics Institute (DMI) – to promote and advocate for its recommendations in a sustained and consistent manner.

The Developmental Mathematics Institute, created under the auspices of this grant, took as its goal the continuous improvement in success rates among developmental mathematics students. The project plan called for the DMI to be established to assume overall coordination of the project, assess progress being made toward project goals, monitor the program budget and expenditures, and report periodically to community college presidents and administrators. The DMI was an outgrowth of the Developmental Education Committee that began in 1996 and coordinated the development of the *Access and Quality* report. It was anticipated that the DMI could continue its activities beyond the period of the grant with support from the community colleges. The colleges would be motivated to provide this support because they believe that system-wide improvements in developmental mathematics would significantly lower institutional costs and improve student success rates. (Note: As the 100% Math Initiative goes forward, it is recommended that the role of the DMI be taken over by a more broadly representative Developmental Mathematics Leadership Group which is described in more detail in the System-Wide Support section of this report).

In the original proposal, it was envisioned that the participating faculty and the DMI would work toward a multi-faceted approach to addressing the concerns about developmental mathematics. This included:

- Developing and implementing an improved assessment and placement system that not only measures incoming students' mathematics ability, but offers guidance and advising on course selection, support services, and individualized educational planning;
- Developing and supporting the broad-based implementing of new and innovative content focusing on both the creative use of interactive technology and the documentation and dissemination of the best instructional methodologies of our veteran mathematics teachers;
- Continuing and expanding faculty support and professional development that focused on both adjunct and full-time faculty; and
- Establishing a continuous evaluation plan that collects baseline, formative, and summative information and feeds it back to the DMI, as well as teaching faculty and campus-level administrators, to foster system-wide improvement.

To support these components of the overall strategy, project funds were used to contract with Wellesley College, Lesley University, and EnabLearning, Inc. to support the cohorts of participating faculty by providing training, consultation, research, and content development services.

The Evolution of the 100% Math Initiative

At its outset, the 100% Math Initiative focused largely on the development, piloting, and dissemination of technological tools for classroom instruction and homework support. While the participating faculty appreciated the place of technology in teaching developmental mathematics students, two issues arose. First, they quickly realized that the web-based instructional and presentation tool was not fully ready for consistent classroom use and it did not facilitate the creation of original content as they had hoped. Second, the faculty didn't believe it was appropriate to incorporate this technology into their classrooms until they had created an overall pedagogical approach to addressing the needs of developmental mathematics students. For these reasons, technology became but a component of the project, while the major focus shifted to pedagogy and systemic change.

As the project's focus shifted, so too did its scope and structure. The original project plan had called for working with five campuses during the first year, and five different campuses in each of the subsequent two years. However, with the new systemic focus, the project leadership realized the importance of engaging faculty from across the Massachusetts community college system to ensure continuity in the planning and implementation of strategies for improving developmental mathematics. As a result, during the final two years of the project, faculty from all fifteen Massachusetts community colleges were actively engaged. With developmental mathematics colleagues from across the state working together, the group was able to develop recommendations for how to make developmental mathematics more effective at the classroom, campus, and system levels. The participating faculty became a "think tank" that could address broad policy and institutional issues, as well as pedagogical and instructional strategies. Rather than simply developing a set of recommended strategies for instructors, the participating faculty placed such recommendations in the context of the related actions required at the campus and system levels to institutionalize and sustain meaningful program improvements. This active collaboration among the participating faculty was a critical element to the success of the 100% Math Initiative. The faculty reached across the differences in program structure and institutional culture on the various campuses to learn from each other and to craft recommendations that could be effectively implemented at any campus. In addition, this communication and collaboration will be ongoing: many of the participating faculty have continued to share ideas and continue to refine the recommendations in this report even after the end of the formal grant period.

Instructional Strategies for Improving Student Performance and Retention in Developmental Mathematics

The 100% Math Initiative produced recommendations in several areas that relate to the project's first goal: improving developmental mathematics instruction. These recommendations are based on well-established principles of effective pedagogy and on the faculty's deeper understanding that resulted from their research and discussion in the course of this project. They are outlined below:

Varied Content Delivery and Active Learning

We assume that developmental mathematics faculty members are sufficiently versed in their subject so that they have accurate information and solid ideas to impart. Given that they know the *what* of developmental mathematics, they must become more aware of *how* they present their ideas. The following recommendations address various aspects of how mathematics concepts are conveyed to students.

Recommendation: Instructors should vary their classroom methodology to actively engage students in the learning process. Students will not absorb as much information if it is thrust upon them only through lectures or readings. According to Hunter Boylan, Director of the National Center for Developmental Education, most developmental education students have an attention span of approximately 15 minutes. If faculty members are not varying their teaching approach every 15 minutes during class, they are losing many students. Simple adjustments could be effective such as taking a break to allow students to discuss concepts among themselves, switching from lecture to group discussion, or allowing a student to demonstrate a concept.

Recommendation: Instructors should incorporate active learning approaches into their classroom methodology. Students learn best by active involvement, so it is important to allow students the opportunity to do hands-on work in every class. The research is very consistent in saying that the diverse students we serve require wide-ranging instructional techniques. About two thirds of today's developmental students are either visual or hands-on learners. They learn best through video clips, computer graphics, and other visual stimuli; by working in problem-solving or other groups; and by being actively involved in the classroom. Possible active classroom activities include critiquing other students' work, writing in a journal, coaching classmates, playing games that simulate "real life" situations and leading classroom discussions. Many of these activities were used in studies by the Continuous Quality Improvement Network (CQIN) and the American Productivity and Quality Center (APQC) (2000).

Research supports the use of active learning techniques, particularly for the population likely to be enrolled in developmental mathematics classes. According to Hunter Boylan, active learning was originally proposed by the noted Brazilian educator, Pablo Friere (Boylan, 2002). Friere argued that traditional learning techniques tended to disenfranchise students from lower class, non-traditional, or minority backgrounds because these methods required them to accept the "truth" of what was being taught even though their experience may have led them to a different "truth." Other researchers assert that active learning is appropriate for developmental education students because of their past failures in traditional learning environments (Tomlinson, 1989). Analysis of the research by Chickering and Gamson (1987) suggests that students must read, write, discuss, or be engaged in solving problems. To be actively involved, students must engage in such higher-order tasks as analysis, synthesis, and evaluation. In short, the basic concept of active learning is that students are directly involved in creating their own learning rather than being passive recipients of instruction (Boylan, 2002).

There is a plethora of writing regarding active learning. For those interested in reading further, the following references can be helpful:

- Bonwell, Charles C. and James A. Eison. (1991). *Active Learning: Creating Excitement in the Classroom*. ASHE-ERIC Higher Education Report. Washington, DC.

- Campbell, William E. and Karl A. Smith. (1995). *New Paradigms for College Teaching*. San Francisco: Jossey-Bass Publishers.

- Johnson, David W., Roger T. Johnson, and Karl A. Smith. (1991). *Active Learning: Cooperation in the College Classroom*. Edina, MN: Interaction Book Co.

Different types of material require different teaching techniques. Instructors need to understand both the content and tools to effectively vary their instructional methodology to meet the needs of the material. The handful of pedagogic techniques that have been used in the past must be expanded as instructors need a broad arsenal of approaches that both match the range of material and actively engage students. These approaches may include lecture, direct instruction, case method, discovery-based inquiry, problem-centered learning, or problem-based learning.

Recommendation: Developmental mathematics instructors should orient their presentation to the real world application of the material. An abstract presentation on rates of growth comes alive when described in terms of a bank account or the stock market. Percentages make more sense in the context of baseball stats. The class examples should be as gender and culturally inclusive as possible. Instructors' presentation and approach can be further varied to include visual, auditory, tactile, small group, individual, and other techniques. Instructors should remember the useful "rule of four" and present information four ways: graphically, numerically, symbolically, and verbally.

Recommendation: Faculty should receive support to understand, be familiar with, and implement the range of instructional strategies and classroom structures required to effectively teach today's developmental mathematics student including:

✤ Lecture

- **Talk and chalk:** a "traditional" classroom where the focus of attention is on the instructor who presents almost exclusively by lecturing and writing on the board.
- **Interactive whiteboards:** large writing surfaces visible to students, whereby the written or drawn images can be transferred to either a computer text-document or as a computer image that retains the integrity of the original drawing.

- **PC tablets:** a laptop sized computer with a surface upon which the instructor can draw text, graphs, or equations by hand. These images can be projected to a screen to support a lecture or demonstration and, as with an interactive whiteboard, can be transferred to a document that, in turn, can be sent to the students' computers.
- **PowerPoint presentations:** lectures that use projected computer images powered by a software package that allows for the inclusion of animated and sound-enhanced outlines, graphs, tables, video images, and internet links.
- **Video lectures:** presentations supported and enhanced by video images, often as part of a power-point presentation.

✤ Small Group

- **Collaborative or cooperative learning:** experiences, both in and out of the classroom, designed to encourage students to work together and learn from each other.
- **Contextual education/problem-based learning:** learning that occurs when students develop and/or enhance their understanding of concepts, strategies, algorithms, or techniques by solving multi-step problems, often placed in the context of real data and/or real-life problems, designed to motivate students by demonstrating how these ideas are actually put to use.
- **Discovery-based learning:** guided exercises or activities created to allow students to observe and discover principles, patterns, and concepts on their own or with their peers, in the hopes that the learning that follows will be more meaningful and more easily retained.
- **Hands-on group activities:** cooperative, often discovery-based learning where students physically work with "manipulatives" such as blocks, cubes, fraction circles, or any physical objects that embody or exhibit the principle to be learned.
- **Peer review of student work:** a form of cooperative learning where by students evaluate and/or critique each other's work.
- **Technology labs:** rooms with computers in which instructional software or interactive programs have been loaded, or learning activities designed to be completed using (usually) computer technology.

✤ Individualized Instruction

• **Computer-mediated instruction:** computer based software used to enhance or facilitate learning. Also called Computer Assisted Instruction, it is a category of learning tools that include software specifically designed for students with learning disabilities.

• **Distance learning:** instruction that occurs with student and instructor at different locations and, possibly, at different (asynchronous) times. The instruction can be computer and/or web based or can be recorded video or live interactive video.

✤ Self-Paced Instruction

• **Self-paced instruction:** is a program of learning, often supported by computer instructional software, whereby students study on their own and at their own pace and take exams and quizzes when they are ready. Students move on to new material only when they have been successful with the preceding lesson.

Recommendation: Similarly, textbooks should be selected to include varied instructional methodologies, be contextually rich, incorporate numerous applications of the material, and be activity-based and hands on. In courses that use a textbook (offered to students either in print or online), that textbook can be the students' most fundamental tool. Depending on the course and level, there may be only a limited number of textbooks that meet these criteria. The school's developmental mathematics coordinator and/or mathematics department head can assist as necessary or act as resources to instructors regarding the selection of appropriate textbooks. Developmental mathematics instructors should consider making the selection of textbooks a collaborative process, working together to find consensus on the selection of textbooks that will most effectively meet the needs of their students.

Student Learning Styles

There is a substantial amount of research on different learning styles, both on students' own styles and instructors' strategies to address them. Students preferentially take in and process information differently: through seeing and hearing, reflecting and acting, reasoning logically and intuitively, analyzing and visualizing.

Teaching "styles" also vary. Some teachers lecture while others demonstrate or lead students to self-discovery. Some focus on abstract principles and others on applications; some emphasize memory and others understanding. When mismatches exist between learning styles of most students in the class and the teaching style of the instructor, the students may become bored and inattentive, do poorly on tests and/or get discouraged about the course, the curriculum, and themselves (Felder).

The American Mathematical Association of Two-Year Colleges (AMATYC, November 2005) has developed standards for teaching mathematics in the first two years of college. The learning styles standards are based on research that shows the importance of a match between faculty teaching techniques and student learning styles. One study revealed that most instructors teach the way they learn best or the way they were taught. As a result, about two-thirds of the faculty were teaching to approximately one-third of the students. (Nolting).

A student's learning style can be identified using any of a number of available instruments. Some students have a different learning style for mathematics than they do for other academic subjects such as English and history so a learning style inventory specifically designed for mathematics should be used. (Several available learning style assessment instruments and inventories are presented in Appendix E.)

AMATYC recommends that students and faculty be aware of different learning styles and implement supportive strategies to maximize student learning in mathematics. Faculty can work to understand student learning styles and become aware of one's own teaching style, help students identify their mathematics learning style(s), and implement multiple instructional strategies to address multiple learning styles. In addition, departments and/or institutions can provide academic resources to develop and support multiple instructional strategies; and provide professional development opportunities on learning styles for mathematics faculty and student support staff (AMATYC, 2005).

Professional development for teachers in instructional approaches for varied learning styles is essential. Such professional development may include workshops, mentors, peer groups, and print-based and web-based resources for self-directed study. In addition, the statewide Developmental Mathematics Leadership Group (DMLG, which is described later in this report) will maintain a range of materials, sample lessons, and other resources on its website,

along with a list of relevant organizations that conduct research and provide models and methods for addressing the needs of students with different learning styles.

Developmental mathematics students' differences in learning styles derive from several factors, including:

- Diagnosed and undiagnosed learning disabilities;
- Variations in span of attention;
- Issues related to race, ethnicity, language, and other aspects of cultural background;
- Gender;
- Family history of attending college, i.e., whether a student is the first in his or her generation to attend college;
- Brain dominance issues;
- Visual vs. auditory learners.

While teachers should be aware of these issues and develop the tools to address them, the college's support staff, the students' other teachers and the students themselves should work with the teacher to determine the important factors in a student's learning style. Campus teaching faculty and support staff need to help students become aware of their own learning styles by offering self-assessment instruments and providing students with tips and tools to learn the material more effectively in light of their individual learning styles. Once the instructor is aware of learning style issues, however, he or she should have the pedagogic tools to respond to them effectively.

> **Recommendation:** The 100% Math Initiative strongly recommends that Massachusetts community colleges implement systematic training and professional development in learning styles to increase instructors' awareness and provide the relevant tools.

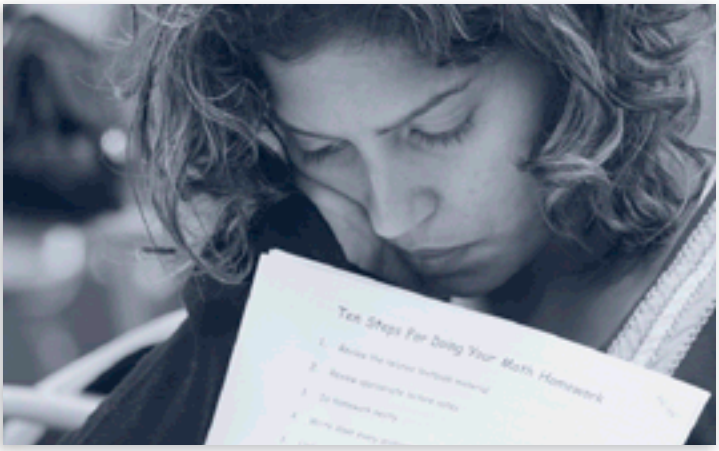
Any discussion of learning styles would not be complete without a reference to the issue of learning disabilities. Like all students in all colleges, some developmental mathematics students have diagnosed or undiagnosed learning disabilities. Faculty should be familiar with evidence of learning disabilities and vigilant about noting it to students and their counselors. However, there is a level of learning disabilities beyond which community colleges cannot reasonably prepare their developmental mathematics faculty.

Recommendation: It is recommended that there be strong and systematic collaboration between teaching faculty and other campus support staff who have the background and experience to work with learning-disabled students, including learning disability specialists and learning lab staff. Because these specialists may not have extensive mathematics background, collaboration and joint activities between them and the developmental mathematics instructors would be essential.

Homework and Beyond

The role of homework and out-of-class activities is an integral component of success for developmental mathematics students. There are simply not enough contact hours in developmental mathematics courses for students to absorb information and develop their skills through in-class activities alone.

A Spring 2004 study by Enablearning, Inc., one of the contracted technical assistance providers for the 100% Math Initiative, investigated the relationship between homework and success in developmental mathematics (Reeves, Spring 2004). Conducted in cooperation with Massachusetts community colleges and using a new homework technology developed by Enablearning, instructors in the study assigned homework problems to each student individually. The difficulty of each problem was matched to the student's learning progress to assure each student received relevant homework problems. Each student was assigned problems until that student achieved mastery in the concept and received immediate visual feedback on his/her progress. The system also tracked the performance of students throughout the semester and provided information to the instructor on individual and group progress in assignments for intervention and instructional focus. The results of this study indicated a strong relationship between persistence in the completion of homework assignments and indicators of successful completion of developmental mathematics courses. There was also a strong positive correlation between the percent



of homework assignments completed by the student and the final grade or quality point score for the course.

Another similar study concerned student use of MyMathLab, an innovative series of online courses that supplement Pearson Addison-Wesley and Pearson Prentice Hall mathematics and statistics textbooks. In a study comprised of 193 students enrolled in Finite Mathematics at a Catholic college during fall, 2004 and spring, 2005, data included final exam scores, final course grades, and active use of MyMathLab. The study concludes with the following statement: "The results of the ANOVA, a statistical analysis, indicate that we should reject our hypothesis that indicated that there is no significant difference in final exam scores in Finite Mathematics, between students grouped by use of MyMathLab. Specifically, the mean final exam score for students who utilized MyMathLab was 84.3% while the mean final exam score for students who chose not to use supplemental learning materials available in MyMathLab was 72.1% (Speckler, Fall, 2005)."

Every classroom teacher knows that many students do not consistently do their homework. Even for those who do, they often do not get maximum benefit from it for several reasons:

- Low quality of homework completed;
- Lack of timely feedback;
- A lack of students' understanding of the need for practice and learning-by-doing;
- Time constraints for the students (developmental mathematics students are more likely to have life pressures that exacerbate these time constraints);
- Lack of good study skills that can be applied to homework;
- Lack of family and other outside supports, resulting in homework done in isolation;
- Too much homework as a result of over-registration and course over load (including registration into inappropriate college level courses).

Some of these cannot be affected through the efforts of the developmental mathematics instructor. However, there is one area in which the instructor can have a significant impact: consistently conveying to students the importance of homework completion and quality. Nearly all teachers

assign homework, but when those assignments are not assessed or reviewed, teachers inadvertently send the message that they do not value homework as a critical component of the course.

> **Recommendation:** Instructors should develop and implement strategies for conveying the value of homework including emphasizing it in the syllabus, providing incentives for completing homework, checking it regularly, and providing feedback to the students. Students could save their out-of-class work as a portfolio that instructors could review to identify difficulties. (Note: Such running records of student work are an important feature of automated homework systems, discussed below.) Teachers may not be able to grade and return homework every day, but they must show students that homework is part of the class content, not an add-on or busywork.

Many developmental mathematics students do not have the full range of study skills and "habits of mind" that can help them succeed. Along with test taking, note taking, and other skills related to their classroom participation, students need to learn how to use homework and self-study effectively.

> **Recommendation:** The community colleges should develop supports for homework help and supervision, including staffed mathematics centers that provide tutoring, reference materials, online help, and supplemental instruction. Instructors should actively promote the use of these resources by employing a positive messages and creative scheduling to overcome some of the common barriers to using them.

There are a number of electronic homework systems that address issues and barriers related to students successfully completing their homework. The software is attractive and engaging for students, provides instant feedback, tracks student skills over time, and systematically increases the complexity of problems in response to student progress. At the same time, the programs save instructors' time because they guide students through the learning process, grade their homework online, and generate data for planning and evaluation. (An annotated inventory of electronic homework systems is included in Appendix C.)

Skills Related to the Learning Process

Students in developmental mathematics courses are often not prepared for college level work because they lack adequate skills in and understanding of the learning process itself. To succeed at mathematics, it is often helpful for students to broaden their understanding of how mathematics is used in their lives. Similarly, they must understand that their school success relies on more than what happens in the classroom. As part of improving developmental mathematics programs, community colleges need to allocate resources to improving students' ability to learn. These skills and understandings include:

- Understanding the importance of attendance and participation;
- Homework strategies;
- Self-awareness of personal learning style;
- Creating effective learning environments for out-of-class work;
- Time management
- Note taking;
- Test taking;
- Active listening;
- Practice strategies;
- Ability to transform concrete skills into conceptual understanding and real world applications;
- Working in groups;
- Seeking help;
- Effective and efficient use of mathematics textbook and other available resources;
- Estimation skills and testing for reasonableness;
- Overcoming math anxiety.

Recommendation: Developmental mathematics instructors should identify and implement strategies for assisting students with skills and understandings related to the learning process (sometimes referred to as study skills), and integrating these skills directly into their course curriculum and classroom activities. Instruction should be explicit and transparent about what we want students to do in terms of note taking, how to use the specific features of the of textbook, etc.

Campus Organizational and Administrative Practices

Overview

To successfully implement the recommendations in the Instructional Strategies section of this report, there must be a level of commitment at the campus level that matches and supports the efforts of instructors in the classroom. Massachusetts' community colleges need to structure programs and allocate resources to both promote student success in developmental mathematics and increase their faculties' capacity to teach effectively. The 100% Math Initiative generated a number of specific campus-level recommendations that are described in this section.

A developmental program's placement within a college's organizational structure plays an important role in its potential for success. Hunter Boylan makes it clear that retention is an institutional, not a program, responsibility:

"Developmental education does not work well when an institution's chief academic officer tries to pretend that it does not exist. Developmental education does not work well when it is consigned to the periphery of institutional endeavors. Developmental education does not work well when it is a random, nonsystematic effort carried out by uncoordinated units spread across the institutional flow chart. Developmental education does not work well when faculty complain that "these students don't belong here." Developmental education does not work well when academic advisors tell students that they should try to avoid taking non-credit developmental courses and get on with the regular curriculum." (Boylan, 2002)

Centralization offers the optimal design for developmental education's operation. According to Boylan, centralization refers to an organizational arrangement in which developmental courses and services are highly coordinated, housed in a single department or program, and headed by a chair or director. The weight of the research clearly indicates that centralization enhances student success (Boylan, 2002). Research suggests that any variation of centralization appears to result in stronger program performance than completely decentralized organizational arrangements, with the most centralized programs achieving the greatest success. This is particularly true when the developmental education's mission receives strong institutional support.

Reviewing several studies, John Roueche, a national leader in developmental education from the University of Texas at Austin and his colleagues consistently found that centralization of program operations correlated with student success. A Texas study found that centralized developmental education programs produced higher post developmental education pass rates on a state mandated test than decentralized programs. Results from the National Study of Developmental Education showed that centralized program structure correlated with improved student retention and higher pass rates in developmental education. Finally, a study sponsored by the

Continuous Quality Improvement Network/ American Productivity and Quality Center found that, among best-practice institutions, "successful developmental education programs are structured as academic departments within their institutions" (Boylan, 2002). In sum, there is overwhelming evidence that the best organizational arrangement for developmental education is a centralized program combining a variety of courses and services.

Recommendations Regarding Program Structure and Student Support

Based on the project participants' experience on their own campuses, an in-depth analysis of current policies and practices at Massachusetts' fifteen community colleges, and research regarding successful and promising practices from other states, the 100% Math Initiative developed the following program design recommendations:

a) Campus developmental mathematics coordinator: As part of the centralization of developmental education discussed in the overview, there should also be a position established of campus-wide developmental mathematics coordinator. This position should have considerable responsibility for developmental mathematics curriculum and instruction, and should be funded through stipends and/or course reassignment(s) sufficient to make the job attractive to a campus's most talented faculty. The coordinators' responsibilities should include:

- orienting developmental mathematics faculty to the school's requirements and policies;
- coordinating and promoting the developmental mathematics faculty's professional development;
- supporting curriculum development;
- creating and maintaining an information clearinghouse;
- supporting the process of instructional change;
- observing, mentoring, and supporting developmental mathematics instructors;
- assisting the dean with hiring developmental mathematics staff;
- acting as liaison to the mathematics department to facilitate alignment;
- acting as liaison to the learning disability and counseling service departments;
- acting as campus liaison to the statewide developmental mathematics leadership group.

b) Developmental mathematics handbook and orientation for instructors: A comprehensive handbook for developmental mathematics instructors should be developed to include materials concerning administrative and logistical issues, curriculum and syllabus information, key elements of the recommended instructional approaches in light of characteristics of the student population, and an inventory of academic support resources. The handbook will reflect each campus's culture, resources, and philosophy, but will also have common elements that reflect systemic

needs and initiatives. This handbook will be a key element of the orientation for new faculty, especially adjunct faculty.

c) Training and professional development for instructors: A series of workshops should be developed for developmental mathematics faculty (especially for new faculty, who are most often adjuncts) that address all areas covered in this report including strategies for accommodating different learning styles, the integration of study skills into instruction, the use of technology, creative strategies for engaging students, and student advising and support. The training should be provided by experienced community college instructors, and resources should be allocated to support the participation of adjunct and other faculty. Possibly, professional development activities for faculty can be offered in multi-campus clusters.

d) Course entrance, exit, and completion expectations: Each developmental mathematics course should have specific competency-based expectations that a student must meet before s/he can move on to the next course in the sequence. These can include student portfolios and/or departmental final exams, which measure student proficiency in the minimum instructional objectives of the particular course.

e) Scope and sequence of developmental mathematics: The developmental mathematics sequence should consist of three courses: Foundations of Mathematics, Foundations of Algebra I, and Foundations of Algebra II. (The specific topics and competencies recommended to comprise each of these courses are in Appendix D). This sequence is paced to be most beneficial to most students and also effectively prepares them to succeed in future college mathematics courses.

f) Student orientation: Students should receive a complete orientation to the developmental mathematics program (including content and sequence of courses, student assessment and placement process, expectations of students, available support resources, etc.). Specifically with regard to the placement tests, many students do not fully understand how to approach these tests or how the results are used. The community colleges should provide information and support to help students prepare for the placement test (from a test-taking perspective as opposed to

a content perspective), including an orientation to the purpose and design of the test. Ideally, this orientation should be integrated into the existing orientation that all incoming students receive.

g) Student advisement: Students should have access to advising on course and instructor selection, accessing the available support services, approaches to self-study, and self-assessment. In addition, each developmental mathematics students should be assigned a faculty member to whom he or she can go during the semester to discuss difficulties or questions the student may have. Appropriate training and professional development for faculty and staff in strategies for effective student advising should be offered.

h) Student support services: Developmental mathematics students should have access to a range of support services related to their developmental mathematics experience, including remedial tutoring, homework help, and test preparation. Funding should be made available for support services staff and related resources such as computer labs and study centers.

i) Contact time: Community colleges should review and reconsider the amount of contact time for developmental mathematics. The contact time should be sufficient to enable instructors to implement all aspects of effective instruction and active learning for this population, including the integration of study skills into classroom activities.

j) Community of learners: The community colleges should develop learning communities, i.e., cohorts of developmental mathematics students taking a set of courses together. Although this may present some administrative and scheduling challenges, it will provide substantial support to the developmental mathematics students who, as was discussed earlier, tend to feel isolated when not yet a member of a department or field of concentration.

System-Wide Support

In addition to changes at the classroom and campus levels, the developmental mathematics community as a whole needs a strong locus of research, data gathering, dissemination, communication, and advocacy that will promote reform across the system. Both Roueche (1999) and Boylan (2002) stress the importance of collaboration with other campus units and with other colleges as essential to improve the quality and effectiveness of developmental education.

There are several models of system-wide or statewide support for developmental education. Many states have initiated strategies for addressing the several issues regarding underprepared students at the postsecondary level. An excellent resource for these activities is found in a report by the State Higher Education Officers. (Crowe, 1998).

Some models have focused on offering financial aid to encourage students to complete college preparatory courses and, as a result, reduce the need for developmental education. Arkansas, Georgia, and some other states offer innovative scholarship programs to encourage completion of college preparation programs. The Academic Scholarship program in Arkansas offers a full set of core courses. Georgia offers the HOPE scholarship that provides financial aid to any Georgia high school graduate who completes a defined set of high school courses with a B average.

Other models, notably Maryland and Arkansas, have emphasized K-16 partnerships. In partnership with the Education Trust, the National Association of System Heads (NASH) supports a network of public higher education, K-12, and civic leaders who are implementing statewide K-16 improvement strategies in their states. Members of the State K-16 Network are committed to working together to coordinate education improvement efforts from kindergarten through college. Two key issues in secondary-postsecondary collaboration are paramount: curriculum and standards alignment so that all students graduate high school ready for college without need for remediation, and teacher preparation and quality so that secondary and postsecondary teachers are prepared and able to teach all students to high standards.

In Massachusetts, the community college system can sustain the classroom and campus-level innovations through system-wide efforts such as cross-campus professional development, a website where faculty and administrators can share ideas and promising practices, an annual conference (perhaps in collaboration with other mathematics education or teaching and learning conferences), and leadership development in the sector. The 100% Mathematics Initiative has initiated considerable positive momentum among those in community colleges who are concerned with developmental mathematics. It is our intention to continue bringing people together to advance students' success.

Recommendation: Establishing an independent statewide Developmental Mathematics Leadership Group is a critical step and core component in sustaining the implementation of the 100% Math Initiative's recommendations. The DMLG's goal is to significantly increase student success in developmental mathematics throughout the Massachusetts community college system. To do so, the DMLG will research, develop, recommend, disseminate, and monitor instructional content, course delivery methods, and ongoing faculty development. One of the most significant and visible roles of the DMLG is to advocate for increased funding that will support more full-time faculty, to promote the role of online resources for developmental mathematics, and to coordinate the revisiting of developmental mathematics assessment policies and protocols (including the computerized placement test).

The Developmental Mathematics Leadership Group recognizes that each campus has unique needs and circumstances, and therefore, each must maintain overall independence in the development and success of its mathematics curriculum. Furthermore, the DMLG endorses the principles of academic freedom that allow individual approaches to common curricular goals. Nevertheless, it supports the notion that communication, cooperation, and as much consistency as possible would be to the benefit of all developmental mathematics faculty, departments, and students.

The faculty who participated in the 100% Math Initiative developed the following initial list of responsibilities for the Developmental Mathematics Leadership Group. These duties would evolve over time as circumstances change and reforms are implemented.

- Provide forums for the interchange of ideas and facilitate continued communication and cooperation among campus mathematics educators.

- Research and disseminate innovations in developmental mathematics curricula, instruction, student support, and assessment.

- Maintain the website (http://cit.necc.mass.edu/100math) established under the auspices of the 100% Math Initiative grant. The site will provide a centralized resource for sharing of curricular ideas and program structure.

- Foster communication within the community and disseminate ideas relevant to developmental mathematics, the DMLG will publish a bi-annual newsletter aimed at all Massachusetts community college mathematics faculty and others interested in developmental mathematics education.

- Run at least one conference each year (perhaps in collaboration with other related conferences) that would provide professional development opportunities for adjunct faculty.

- Convene a statewide task force of developmental mathematics instructors and community college administrators to investigate the accuracy of the computerized placement test for appropriate student placement into developmental mathematics courses and to develop consistent statewide placement recommendations and testing policies and procedures for student assessment and placement.

The Developmental Mathematics Leadership Group is envisioned to include a representative from each of the community colleges, with those representatives responsible for teaching and/or coordinating developmental mathematics on their respective campuses. The group will meet regularly, and have subcommittees and working groups that will meet additionally as necessary. Each of the community colleges should commit the resources necessary to compensate its campus representative for his or her participation on the DMLG, as well as a modest contribution to the expenses of the DMLG as a whole.

Over time, the Developmental Mathematics Leadership Group will develop affiliations, either formally or informally, with the American Mathematical Association of Two-Year Colleges, the New England Mathematical Association of Two Year Colleges, the National Council of Teachers of Mathematics, and similar groups. In addition, Developmental Mathematics Leadership Group members may present specific strategies and initiatives at these groups' conferences.

As the Developmental Mathematics Leadership Group develops as a locus of advocacy and communication, it may take on other roles as well. It can play a significant role in system-wide professional development by hosting conference and other events that promote more sharing of resources and approaches. Its website can become an electronic resource library and discussion vehicle within the developmental mathematics community.

The Developmental Mathematics Leadership Group would offer the broad level of support that will enable more students to achieve greater success in developmental mathematics courses. By fostering changes at the system level and helping colleges incorporate best practices into their classrooms, the DMLG will facilitate and support achievement by individual students. At the same time, the DMLG will promote the importance of developmental mathematics statewide so that it is understood and funded at a level commensurate with the significant current and future need.

Conclusion: Looking Ahead

While developmental education has been part of American colleges for at least 350 years, Massachusetts has only recently conducted a close, systematic analysis of how it can be improved. These efforts are focused on the thousands of students who rely on these courses as the foundation for the next level of their college education. These students are putting in tremendous effort, often at significant sacrifice, and we owe them the finest, most cohesive developmental education program we can offer.

The difficult issues associated with developmental education (including large numbers of students, under-prepared faculty, and low success rates) are particularly noticeable in developmental mathematics. A lack of mathematics proficiency has become a significant barrier to many community college students, blocking them from obtaining the economic, civic, and intellectual opportunities of the 21st century. Rethinking, reorganizing, and infusing energy and resources into developmental mathematics will go a long way toward removing this major hurdle and will help return the state to its once-dominant position in technology and engineering.

The faculty of the 100% Math Initiative believe that the recommendations in this report can have a significant, positive impact on student enrollment and retention, general improvement in student academic performance, and overall student success. Implementing these recommendations can also enhance the overall effectiveness and efficiency of campus administration.

The 100% Math Initiative has made significant strides over the last three years in understanding the issues in developmental mathematics education that have led to a poor success rates for students. The participating faculty have analyzed student needs

and compared best practices at Massachusetts' community colleges and other programs around the country, and review relevant research. With this greater understanding, they have created recommendations that will elevate developmental mathematics teaching to a level at which students will move expeditiously and confidently to the next level of their college education. This positive impact on the students' success will have a similarly constructive impact on campus enrollments, persistence and graduation rates, revenues, and the overall financial well being of the community colleges.

While the faculty involved in the 100% Math Initiative are committed to this goal, they know they cannot make the necessary changes themselves. Improving developmental mathematics requires changes that only campus administrators and deans can put into place, and shifts of thinking at the systemic level that fall under the purview of college presidents and legislators. These changes are feasible, affordable, and entirely practical. Improved developmental mathematic education is well within reach. Working together, the state's higher education practitioners and leadership can effect changes that will place Massachusetts' community college students on the road to success.

APPENDIX A

Report of the 100% Math Initiative

Summary of Recommendations

Regarding Instructional Strategies

1) Instructors should **vary their classroom methodology** to actively engage students in the learning process. Faculty need support to understand, be familiar with, and implement the range of instructional strategies and classroom structures required to effectively teach today's developmental mathematics student including lecture, small group, individualized, and self-paced instruction. Because students learn best by active involvement, instructors should provide students the opportunity to do hands-on work in every class, and should orient their presentation to the real world application of the material.

2) **Textbooks** (offered to students either in print or online) should be selected to include varied instructional methodologies, be contextually rich, incorporate numerous applications of the material, and be activity-based and hands-on. Developmental mathematics instructors should consider making the selection of textbooks a collaborative process, working together to find consensus on the selection of textbooks that will most effectively meet the needs of their students.

3) Developmental mathematics instructors should be aware of **different learning styles** among their students and adjust their instructional approach accordingly. Community colleges should implement systematic training and professional development in learning styles to increase instructors' awareness and provide relevant tools.

4) There be strong and systematic collaboration between teaching faculty and other campus support staff who have the background and experience to work with **learning-disabled students**, such as learning disability specialists and learning lab staff.

5) Instructors should develop and implement strategies for conveying the **value of homework** including emphasizing it in the syllabus, providing incentives for completing homework, checking it regularly, and providing

feedback to the students. The community colleges should develop supports for homework help and supervision, including staffed mathematics centers that provide tutoring, reference materials, online help, and supplemental instruction.

6) Developmental mathematics instructors should identify and implement strategies for assisting students with **skills and understandings related to the learning process** (sometimes referred to as study skills), and integrating these skills directly into their course curriculum and classroom activities.

Regarding Program Structure and Student Support

7) There should be **developmental mathematics coordinator** for each campus. This position should have considerable responsibility for developmental mathematics curriculum and instruction, and should be funded through stipends and/or course reassignment(s) sufficient to make the job attractive to a campus's most talented faculty.

8) A comprehensive **handbook for developmental mathematics instructors** should be developed that includes materials concerning administrative and logistical issues, curriculum and syllabus information, key elements of the recommended instructional approaches in light of characteristics of the student population, and an inventory of academic support resources.

9) A series of **professional development workshops** should be developed for developmental mathematics faculty (especially for new faculty, who are most often adjuncts) that address strategies for accommodating different learning styles, the integration of study skills into instruction, the use of technology, creative strategies for engaging students, and student advising and support. The training should be provided by experienced community college instructors, and resources should be allocated to support the participation of adjunct and other faculty.

10) Each **developmental mathematics course should have specific competency-based expectations** that a student must meet before s/he can move on to the next course in the sequence. These can include student portfolios and/or departmental final exams, which measure student proficiency in the minimum instructional objectives of the particular course.

11) The **developmental mathematics sequence should consist of three courses:** Foundations of Mathematics, Foundations of Algebra I, and Foundations of Algebra II. This sequence is paced to be most beneficial to most students and also effectively prepares them to succeed in future college mathematics courses.

12) Students **should receive a complete orientation to the developmental mathematics program** (including content and sequence of courses, student assessment and placement process, expectations of students, available support resources, etc.).

13) Students should have **access to advising** on course and instructor selection, accessing the available support services, approaches to self-study, and self-assessment. In addition, each developmental mathematics students should be assigned a faculty member to whom he or she can go during the semester to discuss difficulties or questions the student may have.

14) Developmental mathematics students should have access to a range of **support services** related to their developmental mathematics experience, including remedial tutoring, homework help, and test preparation. Funding should be made available for support services staff and related resources such as computer labs and study centers.

15) Community colleges should review and reconsider the amount of **contact time** for developmental mathematics. The contact time should be sufficient to enable instructors to implement all aspects of effective instruction and active learning for this population, including the integration of study skills into classroom activities.

16) The community colleges should **develop learning communities,** i.e., cohorts of developmental mathematics students taking a set of courses together. Although this may present some administrative and scheduling challenges, it will provide substantial support to the developmental mathematics students who tend to feel isolated when not yet a member of a department or field of concentration.

Regarding System-Wide Support

17) There should be an independent **statewide Developmental Mathematics Leadership Group** established to sustain the implementation of the 100% Math Initiative's recommendations. This group will research, develop, recommend, disseminate, and monitor instructional content, course delivery methods, and ongoing faculty development. One of the most significant and visible roles of the Developmental Mathematics Leadership Group is to advocate for increased funding that will support more full-time faculty, to promote the role of online resources for developmental mathematics, and to coordinate the revisiting of developmental mathematics assessment policies and protocols (including the computerized placement test).

APPENDIX B

Report of the 100% Math Initiative

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APPENDIX C

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Annotated List of Selected Electronic Homework Systems

A. Eduspace™

Eduspace™ (www.eduspace.com) is Houghton Mifflin's online teaching and learning tool. Each text supported by Eduspace™ comes with pre-created homework assignments and exercises to correspond to the text. The instructor determines whether the assignments are graded or un-graded and how much each assignment counts toward the final grade. As with other computerized systems, it includes a course management system to allow design of the tests, automate the grade-book, and monitor student progress. Eduspace™ provides online and also real tutoring support that is even more valuable when on-campus tutoring centers are closed. Houghton Mifflin has a Dedicated Media Specialist Team, Online Media Consultants, and Faculty Advisors to help alleviate some of the challenges. Additionally, there is support for in-class demonstration to students, and developing customized content, using an instructional designer.

B. EnableMath™

This program is the product of a partnership between Enablearning, Inc., an educational technology company, and Noel-Levitz, Inc., a higher education retention consulting firm. EnableMath™ provides the student with a comprehensive web-based homework system, supported by one-step-at-a-time examples and dynamic visual concepts. Faculty are provided with enhanced classroom decision making and intervention capabilities through access to system-generated performance data as well as support from Noel-Levitz in effective use of data to improve student retention and success in developmental mathematics.

C. iLrn™

iLrn™ is Thomson's system for integrated testing, tutorials, and course management on the web (www.ilrn.thomsonlearningconnections.com).

D. MathZone™

MathZone™ is a McGraw-Hill product (www.mhhe.com/math/mathzone) "that combines book-specific practice and tutorial content with automatic, online assessment. An instructor can use the algorithmic capabilities to generate multiple versions of assignments and quizzes; edit provided material or create one's own. A grade book function is included.

E. MyMathLab™

MyMathLab™ is a website (www.coursecompass.com) supported by Addison-Wesley that provides students with a centralized point of access to a variety of on-line resources available with numerous texts. The pages of the actual book are loaded into MyMathLab™, and as students progress through the book they can link to supplementary resources such as tutorial software, interactive animations, and audio and video clips. Instructors can assign specific homework problems (from a databank of problems), quizzes (either practice or real) and tests, and track the results; or, let MyMathLab™ generate personalized study plans for students. Complete course-management capabilities, including communication tools (e-mail) for course participants, can make for a ready-made distance-learning course. Access can be packaged with the textbook. Another feature is the ability to create a "coordinator course", whereby the course coordinator can duplicate assignments for other teachers; this may be a great boon for adjuncts or others who may not have the time or expertise to set up their own homework systems. The "coordinator course" is also a benefit for an individual instructor who teaches multiple sections of the same course. There also are several Adjunct Support manuals available for several of the textbooks, and more planned for the future.

APPENDIX D

Report of the 100% Math Initiative

Recommended Curriculum and Instructional Objectives for Developmental Mathematics Courses

	Foundations of Mathematics	Foundations of Algebra I	Foundations of Algebra II
1-credit course	1. Read, write and round whole numbers and decimals. 2. Perform basic operations on whole numbers. 3. Evaluate expressions containing whole number exponents and square roots. 4. Apply the order of operations to whole number expressions. 5. Factor whole numbers, define prime numbers and use prime factorization to determine LCM's and GCD's. 6. Perform basic operations on rational numbers (fractions). 7. Perform the basic operations on decimals. 8. Express the meaning of percent as it relates to fractions and decimals. 9. Solve basic verbal applications of percents.	1. Develop a conceptual understanding of different uses of variables. 2. Understand and apply the concepts of expression and equation. 3. Operate on expressions, and recognize and generate equivalent forms. 4. Know the laws of exponents for multiplication, division, and taking of powers. 5. Know the meaning of a negative exponent. 6. Know the distributive property and be able to add like terms. 7. Be able to multiply binomials. 8. Factor out a monomial factor. 9. Factor simple trinomials. 10. Factor difference of two squares. 11. Understand and apply absolute value in terms of distance and square roots. 12. Understand and apply the principles for solving linear equations and inequalities. 13. Understand and apply the concept of slope as rate of change. 14. Understand and apply the Pythagorean Theorem. 15. Apply algebraic methods to solve a variety of real-world and mathematical problems.	1. Rewrite expressions by understanding and applying the concepts of combining like terms, the distributive property, and factoring. 2. Know the difference between simplifying an expression and solving an equation. 3. Understand and apply literal equations to real world problems. 4. Understand and apply the Pythagorean Theorem and properties of similar triangles. 5. Apply algebraic methods to solve a variety of real-world and mathematical problems. 6. Perform operations on simple rational expressions and equations. 7. Explore relationships between symbolic expressions and graphs of lines, paying particular attention to the meaning of intercept and slope. 8. Find the slope of a line from a graph or two points. 9. Find an equation of a line given slope and a point or two points. 10. Understand and apply systems of equations in two variables including their graphs.

APPENDIX D (CONTINUED)

	Foundations of Mathematics	Foundations of Algebra I	Foundations of Algebra II
2-credit course (includes all of the above)	10. Use the basic tools of arithmetic to solve applications problems involving whole numbers, fractions and decimals. 11. Apply the concepts of ratio and proportion. 12. Apply the concept of percent to applications such as percent increase/decrease, discount, interest, commission and sales tax. 13. Write and solve equations for applications of percents.	16. Reduce simple algebraic fractions. 17. Solve ratio and proportion problems. 18. Use tables and graphs as tools to interpret expressions, equations, and inequalities. 19. Create and identify a linear relationship based on patterns in collected data. 20. Use symbolic algebra to represent situations and to solve problems, especially those that involve linear relationships. 21. Model and solve contextualized problems using various representations, such as graphs, tables, and equations. 22. Generalize patterns and relationships using tables, verbal rules, equations, and graphs.	11. Understand and apply direct and inverse proportional reasoning. 12. Write equivalent forms of equations and inequalities and solve them with fluency-mentally, with paper and pencil, and using technology. 13. Understand relations and functions and use various representations for them. 14. Understand and apply the concept of domains and ranges in real world contexts. 15. Find zeros of quadratic functions by factoring techniques, tables, and graphs. 16. Model and solve contextualized problems using various representations, such as graphs tables, and equations.
3-credit course (includes all of the above)	14. Apply the concepts of perimeter, area and volume to basic geometric figures. 15. Use the U.S. and Metric systems in applications of measurements of length, weight and mass and volume. 16. Perform conversions between the U.S. and Metric systems and between units in the same system. 17. Express the meaning of variable and use symbols to represent unknowns. 18. Solve single step linear equations. 19. Evaluate the mean of a distribution of numbers and interpret simple bar graphs and pie charts.	23. Perform basic operations on simple algebraic fractions. 24. Translate among numerical, symbolic, and graphical representations of relationships. 25. Analyze linear relationships by investigating rates of change, intercepts, and zeros. 26. Model problem situations using systems of equations and solve these systems. 27. Understand and apply the concept of independent and dependent variable in real world contexts.	17. Analyze the effects of parameter changes on the graphs of functions. 18. Analyze linear and nonlinear functions of one variable by investigating rates of change, intercepts, zeros, and local and global behavior. 19. Identify linear and nonlinear functions when represented by tables, graphs, and equations. 20. Draw reasonable conclusions about a problem situation being modeled. 21. Model real-world phenomena with a variety of nonlinear functions such as exponential (growth and decay) and quadratic.

APPENDIX E

Report of the 100% Math Initiative

Learning Style Assessment Instruments and Inventories

- Kolb Learning Style Inventory (LSI) for Mathematics.
- Learning Styles Survey by Catherine Jester, Diablo Valley College, Pleasant Hill, CA
- LSI from ELT, retrieved 6/8/2005 from **http://www.activated.dec.act.gov.au.**
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- Brown F. and R. Cooper. (1999). Learning Styles Inventory. Freeport, NY: Educational Activities from **www.academicsuccess.com.**
- **Neil Fleming's** VARK Learning Style Test
- Inventory for Work Attitude & Motivation **iWAM questionnaire**

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