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Theory to Practice
Developmental Mathematics Program: A Model for Change

The Developmental Mathematics Program (DMP) at Texas State University–San Marcos in central Texas has undergone systemic, significant changes over the past ten years. These changes primarily resulted from the alignment to the American Mathematical Association of Two-Year Colleges' (AMATYC) Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus (Cohen, 1995) and Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College (Blair, 2006), incorporation of existing research regarding developmental education in general and developmental mathematics in particular, and infusion of best practices. This article details the impetus for change and provides a description of the current program as well as an explanation of future goals for the DMP.

AMAYTYC calls for a standards-based reform movement that parallels that of K-12 mathematics education stemming from the National Council of Teachers of Mathematics' (NCTM) *Principles and Standards for School Mathematics* (2000). *Crossroads* (1995) was the first standards document for development mathematics. It brought legitimacy and credibility to suggestions for change. For example, the use of technology in the developmental mathematics classroom was quite limited prior to *Crossroads* (1995). And, technology use in developmental mathematics classroom is recommended in the *Crossroads* (1995) "Standard I-6: Using Technology" and "Standard P-1: Teaching with Technology." Thus, there was a need for research regarding calculator use specific to developmental mathematics students (Vásquez, 2000). This resulted in a study led by Vásquez and McCabe (2000), which found that the use of graphing calculators did not significantly impact, either positively or negatively, student academic performance. Critics of calculator use tend to claim that students will do well because they have the calculator performing the calculations. Since the results were neutral, a move to require graphing calculators for students in the program did not receive significant resistance from members of the DMP.

Research about developmental education students guided other programmatic changes for the DMP. According to Boylan (2002), the education provided to developmental students should be based on a combination of theoretical approaches drawn from cognitive and developmental psychology. Instructors should learn about these theoretical approaches and practice combining and implementing them in order to provide effective developmental education. Because they do not have such background in theory or practice, the part-time faculty and/or graduate students assigned to teach developmental mathematics students often turn to a traditional instructional method to teach basic skills. That is, teachers present fundamental skills as step-by-step procedures and reinforce by drill and practice (Krantz, 1999). Proponents of traditional instruction have purported that this approach is the most effective means of gaining fundamental skills. However, research shows that teachers with mathematics anxiety tend to favor traditional instructional techniques and that there is a high correlation between such methods and teacher ineffectiveness (Trujillo & Hadfield, 1999). Research shows a strong case for using non-traditional instructional methods based on curricular innovations such as collaborative learning, which fosters problem solving and reasoning as opposed to rote memorization (Johnson & Johnson, 1991).

Developmental mathematics students need to gain both fundamental and problem-solving skills. They need a strong mathematical foundation for obtaining their educational goals because most degree plans require at least one non-remedial mathematics course. And, in states such as Texas, students must pass state-mandated problem-solving tests in order to graduate from college. In Boylan, Bonham, and Bliss' (1994) article in *Research in Developmental Education*, "Who are the Developmental Students?", demographic data showed that a disproportionate number of minority students, namely African Americans, participated in developmental education. In an informal survey conducted by this author of some universities in Texas, developmental mathematics students tend to outnumber developmental reading and developmental writing students. In a four-year university in Texas by the Mexican border, the ratio of developmental mathematics to developmental reading was 2:1, as was the ratio of developmental mathematics to developmental writing. In north Texas, at another four-year university, the ratio of developmental mathematics to developmental reading was 6:1, as was the ratio of developmental mathematics to developmental writing. At the institution where the DMP is housed, the ratio of developmental mathematics to developmental reading was 50:1, and the ratio of developmental mathematics to developmental writing was 26:1. Although this is not a random sample, developmental mathematics appears to be the most populated content subset of developmental education. Hence, a successful developmental mathematics program has the potential of making mathematics and, consequently, higher education more accessible for minority students.

At the Joint Meetings in Washington, DC, in January 2000, the American Mathematical Society (AMS) and the Mathematical Association of America (MAA) Committee on Teaching Assistants and Part-Time Instructors organized a special session, "Innovative Development Programs for Teaching Assistants and Part-Time Instructors." Most of the professional development available to this population was described as either informal (casual conversations amongst teaching assistants) or traditional (orientation sessions before classes start and regular meetings for a particular course). None of the twelve presentations at the conference discussed formal, concerted, programmatic efforts. Thus, there is an indication that training programs may be void of formal support (including monetary), structure (e.g., making it a requirement and committed involvement of tenured faculty), and activities (e.g., readings, structured discussions, analysis of case studies, observations and videotaping, consultations with experienced instructors, role-playing, and modeling). Moreover, the training issues discussed in this particular session were specifically for teaching assistants, not necessarily part-time faculty. Currently, there exist two programs that utilize teaching assistants and subsequently provide training related to the models, Supplemental Instruction (SI) and the Emerging Scholars Program (ESP). SI is a program developed at the University of Missouri, Kansas City, which trains supplemental instructors to foster effective study skills through content. ESP is a program based on Uri Treisman's research that shows that collaborative work on challenging problems yields increased academic performance in higher mathematics. Neither SI nor ESP specifically addresses the particular needs of part-time faculty. Hence, at

Texas State University–San Marcos, we saw a need for formal training programs for both teaching assistants and part-time faculty.

Description

The goal of the DMP at Texas State University–San Marcos is to increase developmental mathematics students' performance by improving the quality of instruction. The objectives of the program are (a) to foster fundamental and problem-solving skills in developmental mathematics students by helping them to learn when and how to create algorithms as well as when and how to use them and (b) to provide on-the-job training for all developmental mathematics instructors through an instructional framework that requires them to develop and incorporate non-traditional instructional techniques. The overall mission of the program is to provide developmental mathematics students with a positive, nurturing, learning environment, making mathematics and, thus, higher education more accessible.

The primary instructional delivery system is based upon a four-phase algorithmic instructional technique (AIT): modeling, practice, transition, and independence (Vásquez, 2003). The progression begins with teacher-directed instruction of fundamental topics and continues towards a student-directed learning environment for complex topics in a problem-solving context. The ultimate goal is to provide a student-centered learning environment where students gain an understanding of mathematical concepts by creating pertinent algorithms using problem-solving techniques that are reinforced through carefully developed problems, including those based on real-world situations. The AIT provides developmental mathematics students the nurturing environment that they need by employing non-traditional instructional techniques that yield student-authored algorithms for fundamental skills while fostering problem-solving capabilities. An example of this kind of integration is discussed in Vásquez (2003) "Utilizing an Algorithmic Instructional Technique in the Developmental Mathematics Classroom," which describes various examples including linear equations in two variables and sequences.

The program is composed of various components relevant to the developmental mathematics instructors and students. The primary instructor piece is the on-going training that each receives. Prior to each semester, the instructors participate in an intensive three-day workshop. This three-day training session includes:

1. A description of the program;
2. A review of an instructional handbook, especially an orientation to its use (the handbook is a compilation of lessons and

activities, suggesting nontraditional instructional techniques including AIT, created by the program's senior faculty and instructors, and revisions from its previous use as well as suggestions for implementation);

3. A demonstration of several activities, including at least three activities for each of the four AIT phases;
4. An opportunity to practice conducting activities that represent each of the four AIT phases;
5. A discussion on accountability and evaluation requirements such as conducting student surveys and pretests/posttests, maintaining a descriptive log of instructor developed lesson plans and activities, keeping a journal of actual classroom events and personal reflections on the day's events, and collecting samples of student work;
6. An overview, discussion, demonstration, and practice in nontraditional instructional techniques, especially collaborative learning;
7. A workshop on the use of technology in the classroom;
8. Other workshops on topics such as learning styles, professionalism, and multiculturalism that traditional training programs include; and,
9. A meeting of the advisory board charged with proposing recommendations for activity development and alignment, providing suggestions for improving the overall program and ideas for disseminating program results, and assisting other institutions with program adoption.

Other aspects of the program include a weekly seminar, mentoring, and observation/reflection opportunities. The instructors participate in a weekly seminar where they discuss day-to-day administrative issues, lessons, and pertinent literature such as AMATYC's (1995) *Crossroads*. Instructors are also each assigned a senior faculty mentor. The senior faculty mentor conducts regular observations and discusses self-reflections on videotaped classroom instruction.

The developmental mathematics students receive research-based quality instruction, academic support, and several opportunities to communicate their needs. The developmental mathematics courses are limited to approximately 25 students. Although the instructors remain the primary instructional agents, the students must also attend a one-hour lecture where a senior faculty member facilitates discussion about topics from a broad, conceptual perspective, using real-world examples and technology to tie ideas together and reinforce small-group instruction. Thus, the DMP provides students additional instructional time. Instructors must be available for appointments in addition to their required one office hour per day. Moreover, several university offices provide tutoring, including the Student Learning Assistance Center, which also offers Supplemental Instruction to students in the program. Developmental mathematics students are afforded many occasions to provide feedback about the program, including mid-semester and final course evaluations, lesson reaction polls, and results on quizzes and exams.

The most unique aspect of the program is the significance of the resources that are allocated to the DMP from the Department of Mathematics and the University. Typically, part-time/adjunct faculty teach developmental mathematics courses based on a textbook and general course outline. The DMP differs in that senior faculty members collaborate to construct an environment where instructors are carefully guided through well thought-out, research-based training that includes supporting materials and resources. This enables the part-time/adjunct faculty to become highly qualified in teaching and to address the particular needs of developmental mathematics students effectively.

The main training instrument is an instructional handbook that includes directives for teacher behavior such as what to do and how (e.g., whole-class discussion, Socratic questioning), what to stress (e.g., conceptual understanding of absolute value as it relates to the number line), and what type of activities to use (e.g., Traveling on the Number Line). Thus, it encourages inexperienced teachers to incorporate into their lessons more successful non-traditional instructional techniques. The handbook also fosters discussion among developmental mathematics instructors as they create significant contributions to the handbook based on their experiences and feedback from their coworkers. Such interchange allows experienced instructors to play out their important role in assisting with training.

The program is housed in the Department of Mathematics and is directed, coordinated, and managed by three full-time faculty members. At least 30 developmental mathematics instructors per year circulate through the system. Few, if any, of the instructors have received any teacher training. Instructors are typically full-time graduate students in mathematics, and, on average, spend at least two years as developmental mathematics instructors. Records indicate that over 80% of the instructors, after participating in the program, have received comparable positions at colleges and universities and/or are accepted to mathematics education doctoral programs with ease. In fact, the DMP contributes to the training of mathematics education doctoral students at this institution.

Consistent, on-going evaluation focusing on the students, instructors, and the program in general occurs. The evaluation process consists of both a process and product component. The process is monitored and altered based on information from student surveys, observations by the instructor of the students, samples of student work, departmental course examinations, weekly meetings with instructors, maintenance of a descriptive log of instructor-developed lesson plans and activities, instructor participants' journals of actual classroom events, instructor participants' personal reflections on the days' events, and observations of the instructors (at times by an outside person, by a faculty mentor, or by videotape). The product is evaluated by analyzing the results on students' pretests and posttests as compared to those for a control group; their results on a state-level mathematics test, such as the Texas Higher Education Coordinating Board (THECB), as compared to their scores in previous attempts of the test; the results of their performance in their current and subsequent course, College Algebra, as compared to that for previous semesters; and the results of departmental course examinations as compared to those for a control group. Expectations for students include successful completion of the current mathematics course, passing a state-level mathematics test, and successful completion of a subsequent mathematics course. Expectations for teachers include student academic success and improved quality of teaching.

The methods of evaluation include the use of objective performance measures. The intended outcome, to increase developmental mathematics students' performance, is realized if the null hypothesis—if there is no significant difference in the adjusted means of content scores between students receiving the proposed instructional technique and students receiving the traditional instructional technique—is rejected and if there is:

1. A statistically significant increase in test scores (pretest/posttest) at the 0.05 level;
2. A significant increase (at least 10%) of students that pass developmental mathematics courses;
3. A significant increase (at least 10%) of students that pass the THEA; and,
4. A significant increase (at least 10%) of students that pass College Algebra.

Statistical analysis is conducted each semester and has consistently shown that the program is effective. As noted in Vásquez (2004), evaluation centers on general project components, instructors, and students. Insightful qualitative data reinforce these results, including anecdotal claims that the program has been successful (Vásquez, 2004).

An advisory board serves as a recommending body for activity development and alignment. In addition to providing suggestions for improving the overall program and ideas for disseminating program results, the board also assists other institutions with program adoption. The committee members include representatives from national, state, and local organizations such as the National Center for Developmental Education (NCDE), the National Association of Developmental Education (NADE) Mathematics SPIN, the American Mathematical Society (AMS), Mathematical Association of America (MAA) Committee on Teaching Assistants and Part-Time Instructors, American Mathematical Association of Two-Year Colleges (AMATYC) Foundation/Developmental Mathematics Committee, Teachers Teaching with Technology College Short Course Program (T^3 – CSC), and the Texas Higher Education Coordinating Board (TxHECB) Center for College Readiness in the Division for Educational Partnerships.

The program includes partnerships with other colleges and universities around the nation, many of whom have sent representatives to the workshops to receive training and pilot this program at their home institutions. Furthermore, several schools contract assistance with reform efforts by revising their developmental mathematics program using the DMP as a model. Solicitations to present at conferences, assist with related projects such as the Technology in Developmental Education workshop, and host developmental education student interns are also received.

Future

Overall, the DMP maintains a productive atmosphere for all its participants. The program is continuously revised based on active, current research, successes of other programs, and revisiting of standards. For instance, a recent instructor survey indicated a strong need for efficiency in out-of-class duties such as grading. Thus, efforts are currently being made to research and, if necessary, develop new policies, procedures, and mechanisms for streamlining this process. As most publishers provide computer-based instructional products, future goals include reviewing available software packages and determining the role of a hybrid course to address the distinct needs of developmental mathematics students that need a refresher course as opposed to a remedial course (MacDonald, Vásquez, & Caverly, 2002). As recommended in *Beyond Crossroads* (2006), efforts will be made to make the developmental mathematics curriculum more career-based by including relevant, realistic applications such as those dealt with by nurses and technicians. And, efforts to align to the newly-adopted Texas College Readiness Standards are underway. In particular, both Mathematics and Cross-Discipline Standards are being addressed, and as with most standards, both process and product standards are included. In any case, the program team strives to maintain a developmental mathematics program that helps students conquer their fear of mathematics; provides teacher training; offers a framework for the development of innovative lessons including student-centered, technology-based, hands-on, real-world activities; and assists other schools, programs, and organizations with similar endeavors.

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