Best Practices
in
Developmental
Mathematics

Mathematics Special Professional Interest Network
National Association for Developmental Education

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What are Best Practices?

Giving this publication the title of *Best Practices in Developmental Mathematics* is not intended to suggest that one particular practice in developmental mathematics education is necessarily better than others. The publication is simply intended to serve as a forum for developmental math educators to share practices that have produced positive results of one sort or another. It is a collection of materials that represent practitioners' perspectives based in part upon research, but mostly upon experience. While research-based findings have been welcomed, scientific inquiry was not a criteria for submission.

In its current form, the *Best Practices* publication is not meant to be a finished document. In fact, it is hoped that as Developmental Math practitioners read through this material, they will be inspired to contribute to its contents by sending additional materials. The publication will be revised as additional contributions are received. If you are aware of particular practices in developmental mathematics that have produced positive results, please consider contributing to this effort. Materials may be sent to the address below.

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Working with Developmental Students

Those who have been teaching at the developmental level for some time will attest to the fact that teaching developmental mathematics differs substantially from simply teaching mathematics. Developmental instruction addresses not only the remediation of subject-specific deficiencies, but motivational and learning deficiencies as well. In part, this is because the population of students entering college at the developmental level differs from traditional student populations.

Developmental students can represent a surprising mix of characteristics. In the mathematics area, some are capable students who have simply fallen behind, not for lack of ability, but out of disinterest, insufficient effort, lack of seriousness, or some similar reason. If they apply themselves, these students will generally succeed irrespective of how developmental math programs are structured. A second category of developmental math student can be described as those who are adequately prepared for college level study, but have a specific weakness in mathematics. These students typically perform well in college level subjects outside of mathematics, but have difficulty mastering developmental level concepts in mathematics. A third category can be described as students who are motivated to pursue college level work, but are deficient in generalized learning skills as well as math-specific skills. Experience suggests that a fair number of these students can succeed if the developmental environment provides strong support in the learning skills as well as academic content areas. A fourth category involves students who have verifiable (usually documented) learning disabilities. Special accommodations or alternate instructional methodologies may be necessary for some of these students to succeed. A fifth category is comprised of students who have a broad range of deficiencies in multiple areas including mathematical abilities, learning skills, motivation, organizational skills, and others. Students in this category will have difficulty succeeding even when the programmatic aspects of developmental instruction are at their strongest.

Developmental math courses normally serve multiple purposes. The primary goal is to remediate student deficiencies in mathematical skills which are prerequisite to success in required college-level math courses, as well as courses in the sciences, business, or other fields that require basic math and algebra competencies. At many colleges, developmental courses also serve a second purpose of strengthening students' general learning skills prior to their enrollment in regular college courses. A third, although sometimes unspoken, purpose of developmental courses (especially *mathematics* courses) is to serve as part of the "gatekeeper" mechanism by which colleges eliminate students who are not qualified for further study. The fact that developmental math courses play this gatekeeper role gives rise to two somewhat contradictory considerations. On the one hand these courses are intended to *assist* students in meeting college qualifications by overcoming their deficiencies, while on the other hand they are intended to *eliminate* students who are not qualified to continue. This creates a natural tension between setting and maintaining strict standards of performance while simultaneously providing high levels of assistance to a population of students that is known to be below those standards. This inherent tension is a natural part of developmental education.

The relationship between developmental student characteristics and the somewhat divergent purposes served by developmental math courses has also led to discussion about how attitudes affect performance. There is an assumption among many math educators that negative student attitudes toward developmental mathematics impact negatively upon classroom performance. While various studies have been undertaken to determine how *student* attitudes affect performance, work has also been done on how *faculty* attitudes affect student performance. The question of how attitude affects performance also speaks to the larger issue of how environmental factors in general affect developmental mathematics learning. Informal discussions about such issues as math anxiety, classroom environment, the impact of self-image upon classroom performance, and the remedial stigmatization of developmental courses are somewhat commonplace. At the professional level, these concerns have periodically been brought to the forefront by such individuals as Sheila Tobias and others (see below). Without question, developmental math educators need to understand more about the student characteristics, the multiple purposes served by developmental math courses, and the mix of faculty and student attitudes that converge in the developmental mathematics classroom.

Best Practices in Working with Developmental Students

1. Environmental Barriers to Student Success (Keynote address by Sheila Tobias at NADE2001 conference)

Speaking on math anxiety and barriers to student success in mathematics, Sheila Tobias' presentations at NADE2001 examined both instructional and student issues in learning. According to Tobias, the predominant causes of math anxiety are environmental factors created by math teachers. These include pressures created by timed tests, an overemphasis on one right method and one right answer, humiliation of students at the blackboard, an atmosphere of competition, absence of discussion, and other related dynamics that typify the math classroom. For many students, these factors lead to destructive self-beliefs about the math abilities they possess, avoidance behavior, and an unwillingness to explore mathematical concepts in the classroom environment. Coupled with the negative influence of environmental factors is the belief that students who do well in math do so because of native ability, not effort. This misconception, propagated by teachers and society at large, only serves to reinforce negative student behaviors that lead to underperformance in mathematics.

Tobias also discussed what she identifies as a misfit between students' learning characteristics and instructors' teaching styles in mathematics. Only a small percentage of students are "math minded." The rest, she suggests, have learning style preferences or needs that do not fit traditional modes of math instruction. Specifically, students who are high verbal performers need discussion and choice, utilitarian learners need memorizable, predictable learning patterns, and underprepared students need periodic clarification with respect to weaknesses in prior content areas. The typical math class, however, tends to offer only a single, "math minded" approach to learning.

Tobias outlined various ways that college developmental math faculty can respond to these negative factors. First, she emphasized the importance of good diagnostic and placement procedures. This includes the need for colleges to consider the effect of time restrictions on placement testing and for students to be given the opportunity to prepare in advance for placement tests. It also includes the need for faculty to identify and understand the learning style needs and preferences of their students, and for accurate assessment of student disabilities where they exist. Second, instructional methods have to be altered to accommodate the learning characteristics of different kinds of students. For example, instructors should include more discussion and choice in the classroom and less focus on a single right way and right answer to solving problems. As students commonly conceptualize mathematical principles differently than their instructors, the instructor must also be willing to answer "their" questions rather than focusing only on his or her way of conceptualizing a particular principle. This can be accomplished simply by having students submit written questions each day as part of their homework assignment. Citing Philip Uri Treisman's research on the power of group interaction, Tobias emphasized the importance of having students work together with other students as well. Third, as student learning is driven by tests, college instructors need to be aware of certain testing issues. These include the impact of timed testing and test format on student performance. Instructors should experiment with testing by removing time restrictions and varying test types to include open-ended questions, problem solving, or even essay questions, as opposed to just "right answer/wrong answer" questions. Finally, "math clinics" can be useful in helping students deal with the effects of math anxiety or other student-related barriers to learning math. Tobias suggests that math instructors team together with a college counselor to offer voluntary sessions in which students can explore the various factors affecting their individual performance in math.

(Sheila Tobias is the author of 11 books, including *Overcoming Math Anxiety*, *Succeed with Math*, *Breaking the Science Barrier*, and *They're not Dumb, They're Different*. For further information, visit her web site at www.mathanxiety.net)

2. Creating a Participatory Classroom Environment by Jacqueline Bakal, Felician College

Many students who are placed in Developmental Mathematics exhibit math anxiety or a fear of math. Therefore, it is important to create a nurturing, non-threatening environment where students are not afraid to ask questions or make mistakes. Ideally, every student should have the opportunity to speak during every class. The instructor can foster such participation by stressing that students should not feel intimidated by the instructor or other students.

Instead of listing methods for solving certain kinds of problems, the use of a constructivist style of teaching allows students to enter into active dialog with the instructor and each other about alternate methods of solving problems. The instructor can lead students to develop methods based on their own prior knowledge, translating as problems are discussed so that the students gain a clear understanding. By organizing the curriculum in a spiral manner, the students continually build upon what they have already learned.

Allowing *students* to explain problems verbally or at the board not only helps other students, but also those doing the explaining. The best way to understand something is to explain it to someone else! Having two students explain alternate methods for solving the same problem can also strengthen the dialog, as can having students practice new concepts in small groups or pairs.

3. Minority Students and Developmental Mathematics by Meredith A Higgs, Middle Tennessee State University

As college student demographics are changing, developmental education must adapt to meet the needs of these shifts in student population. More students are attending college from a variety of backgrounds, and higher education is experiencing greater student diversity in terms of a wide range of student characteristics such as age, ethnicity, socioeconomic status, and preparedness. However, a cursory review of the literature catalogued in online databases reveals that relatively little literature specifically addresses issues related to minority students in developmental mathematics. Nevertheless, some instructional techniques are suggested.

A study conducted by DePree (1998) of the effects of *small-group instruction* on the outcomes of developmental algebra students indicated that "significant results were found relating to confidence in mathematical ability for several groups who have been underrepresented in mathematics in the past" and that "Hispanic-American, Native-American, and female students showed an increase in confidence in mathematical ability after receiving the experimental (small-group) method of instruction" (p. 3). Further, these increases were statistically significant for Hispanic-American and female students as compared to the control group. DePree also found that "Test data supported the hypothesis that students who received the cooperative, small-group method of instruction would have significantly higher course completion rates ($z = 1.60$, $p = .05$) than students who received the lecture method of instruction" (pp. 3-4).

In a qualitative analysis of two African-American students' perceptions of quality teaching, Powell (2000) indicated that having a "*caring ethic*", being available, conducting positive classroom discourse, and providing clear explanations were reported as characteristics of quality teaching. Powell stated that "a caring ethic is essential for African-American students who face the same problems in the mathematics classroom as other students, but with more exaggerated effects because of racism in this country" (p. 22).

While these two studies suggest that small-group instruction and a caring ethic may be factors that influence minority student success in the classroom, O'Hare (2000) suggests that the instructional commitment to the students of today must include teaching "everything -- what a computer is for, where the library is, how to get a tutor -- regardless of the purported focus of the class" (p. 80). Taken together, these studies only hint at the vast knowledge that is needed to effectively serve developmental minority students and suggest a need for more research on this topic.

Chenoweth, K. (1998, July 9). The new face of college. *Black Issues in Higher Education*, *15* (10), 26-28.

DePree, J. (1988, Fall). Small-group instruction: Impact on basic algebra students. *Journal of Developmental Education*, *22* (1), 2-4,6.

Feldman, M. J. (1993). Factors associated with one-year retention in a community college. *Research in Higher Education*, *34* (4), 503-512.

Kull, K. R. (2000, Spring). A research based model for a developmental education program and its mathematics component. *Education*, *120* (1), 442-448.

Laden, R., Matranga, M., & Peltier, G. (1999, Fall). Persistence of special admission students at a small university. *Education*, *120* (1), 76-81.

O'Hare, S. (2000, August 3). Teaching in the world that is (Instead of the world that should be). *Black Issues in Higher Education*, *17* (12), 80.

Powell, A. (2000, April). *Reflections on exemplary mathematics teachers by two African American students*. Paper presented at the meeting of the American Educational Research Association, New Orleans, LA. (ERIC Document Reproduction Service No. ED 441760).

4. The Effect of Student Attitudes on Performance by Victoria Wacek, Missouri Western State College

There is a basic assumption among many math educators that the attitude of students toward math affects their grade. A four semester study of 1506 students looked at data of success and attrition rates in developmental mathematics courses and attempted to find correlations between attitudes toward math, students' ages, and their grades. A questionnaire asked for students' feelings toward mathematics and their age as nontraditional (25 or older) or traditional (younger than 25). Grades at the end of the semester were noted. Data analysis included descriptive, correlational, ANOVA, and multiple regression. Data from those with neutral feelings were not used in the correlational analyses.

Fifty-nine percent of the students responded with neutral feelings, 23% with negative feelings, and 18% with positive feelings. In all categories of feeling, passing rates were higher than attrition rates. Nontraditional students appeared to feel less negatively toward math than traditional students. However, passing rates were about the same for both. Very weak, but significant, correlations were found between feeling and grade ® = 0.089, $\alpha = .05$), and between age and feeling $r = 0.213$, $\alpha = .01$). No correlation was found between age and grade. Nonetheless, based upon multiple regression analysis, the best indicators for passing would be traditional students who like mathematics.

The correlation coefficients obtained were so low that prejudging a student's grade based on feelings or age may not be practical. Instructors should not equate bad attitude toward math as a route to failure. Advisement should include dispelling students' self-prophecies that they cannot do math. Pedagogy should include techniques to ease the pain of those who dislike math, but are required to take it.

5. Additional Resources

Arem, C. (1993). *Conquering math anxiety: A self-help workbook*. Pacific Grove, CA: Brooks/Cole Publishing Company.

Goolsy, C. B., Dwinell, P. L., Higbee, J. L., & Bretscher, A. S. (1988, Spring). Factors affecting mathematics achievement in high risk college students. *Research and Teaching in Developmental Education*, *4* (2), 18-27.

Hackworth, R. D. (1992). *Math anxiety reduction*. Clearwater, FL: H & H Publishing.

Kogelman, S. & Warren, J. (1978). *Mind over math*. New York: McGraw-Hill.

Tobias, S. (1987). *Succeed with math: Every student's guide to conquering math anxiety*. New York: College Entrance Examination Board.

Tobias, S. (1978). *Overcoming Math Anxiety*. Boston, MA: Houghton Mifflin.

A series of web sites devoted to teaching adults by Roberta Lacefield, Waycross College. Available on the web at <http://members.tripod.com/~Roberta/indexadu.htm>.

Programmatic Considerations

Developmental math programs vary in just about every aspect imaginable. Developmental requirements, course structures, placement policies, instructional methodologies, grading standards, credits awarded, and numerous other facets differ substantially from one college to the next. Even with respect to course content, topics considered to be undergraduate at one institution may be considered remedial at another. The most common description of the developmental mathematics core tends to be the body of material ranging from Arithmetic through Intermediate Algebra. Developmental course work at competitive admission institutions tends to focus on the higher end of this spectrum while open-enrollment institutions typically offer courses at both ends of the spectrum. Many colleges also integrate a geometry component into the developmental math sequence or tailor developmental course offerings to specific majors, covering only content that is directly related to particular fields such as the Allied Health areas. Course structure also varies tremendously with developmental courses carrying anywhere from 0 to 5 semester hours of credit. Some courses are modularized into 1-credit units while others integrate the entire developmental curriculum into a single course. Some institutions require students to complete their developmental requirements within the first year of study; others allow as long as it takes. Performance requirements also vary greatly. While many institutions award grades based on a system of averaging, some require *mastery learning* under which students may not progress to the next unit or chapter of study until they have achieved a minimal level of performance on the current unit. In the mastery learning model, students are usually allowed to retake tests (often multiple times) until success is achieved or testing limitations expire. A number of colleges require *mandatory exit testing*.

Best Practices in Programmatic Considerations

1. Alternative Learning Environments by Dianne F. Clark, Indiana Purdue Fort Wayne

Two programs were implemented allowing students extra time to master difficult topics and employing an alternative testing site with no time limits to reduce test anxiety. The *Flex-Pace* program allows two semesters to complete algebra courses. Each class consists of four groups of eight students, a teaching assistant for each group, and an instructor. Course work is divided into six modules and an in-house workbook is used. Students must pass all modules by completing assignments and scoring 80% on all exams. Exams are taken outside of class in a Test Center. Students may retake tests on different versions until they score 80%.

Students completing all requirements in one semester are given a grade. Students completing less than four modules receive an “F” for the course. Students completing four or five modules receive an “I” and enroll in a follow-up course. These courses are pass/fail, 0 credits, and offered in five-week sessions with a fee equivalent to 1 hour. The classes are structured the same as the original course. Students completing all requirements during the first five-week session receive a grade for the original course. Otherwise they sign up for another five weeks. If they do not finish in the second five weeks, they sign up for a third and final five-week session. Students unable to complete all requirements by the end of this session receive an “F” for the course.

The main feature of the *Out-of-Class Testing* program is that all exams are administered at the Testing Center. Whenever an exam occurs, students are given a five-day period during which they may take up to three versions of the exam. Teaching assistants help students analyze their mistakes between versions. The highest score counts.

2. Common Characteristics of Successful Programs by Linda Hunt, Marshall University

Successful developmental education programs have several common characteristics. Among these are mandatory assessment, mandatory placement, and trained tutors (Boylan, Bonham, & Bliss, 1994; McCabe & Day, 1998; Roueche & Roueche, 1993). According to studies, students participating in programs featuring *mandatory assessment* are significantly more likely to pass their first developmental English or mathematics courses than students in programs where assessment is voluntary (Boylan et al, 1994). Testing should also be mandatory because too many students, especially those who most need assistance, will avoid assessment whenever possible (Morante, 1989). A second characteristic of successful programs is *mandatory placement* (Roueche & Baker, 1986). "It borders on the unethical to know that a student lacks basic skills, but is still allowed to enroll in college courses requiring those skills" (Morante, 1989). While the use of *trained tutors* is a third characteristic of successful programs, tutoring can be a double-edged sword. On the one hand, well-meaning but untrained tutors can do more harm than good (Maxwell, 1997). On the other hand, when tutoring is delivered by trained tutors, it is the strongest correlte of student success (Boylan et al, 1994). Fortunately, tutor training manuals and video tapes are available for purchase (see page 25). Seventy percent of the nation's tutorial programs have a training component (Boylan et al, 1994).

Two other components can also contribute to the success of developmental programs. According to research, *Supplemental Instruction* has consistently been found to improve student performance in developmental courses and to contribute to student retention (Blanc et al, 1983; Rettinger & Palmer, 1996; Ramirez, 1997). The incorporation of studies skills into developmental programs can also contribute to success. However, students have difficulty applying strategies learned in a stand-alone, study skills course to their academic courses. Study skills should be taught as an integral part of the academic course (Arendale May 2000). Studies have also found that students who study alone are most likely to drop out (Arendale July 2000). Based upon this finding, instructors should pay particular attention to attendance and should contact absent students. Study groups should be encouraged to provide a sense of a learning community.

Arendale, David (2000, July). Academic Support Systems. Kellogg Institute, Boone, NC.

Arendale, David (2000, May). Review of Successful Practices in Teaching and Learning. University of Missouri-Kansas City, MO.

Blanc, R., Debuhr , L., & Martin, D. (1983, January/February). Breaking the attrition cycle: The effect of Supplemental Instruction on undergraduate performance and attrition. *Journal of Higher Education*, *54*, 80-90.

Boylan, H. R., Bliss, L. B., & Bonham, B. S. (1997). Program components and their relationship to student performance. *Journal of Developmental Education*, *20* (3), 4.

Boylan, H. R., Bonham, B. S., & Bliss, L. B. (1994). Characteristic components of developmental programs. *Research in Developmental Education*, *11* (1).

Maxwell, M. (1997). *Improving Student Learning Skills*. Clearwater, FL: H & H Publishing Co.

McCabe, R. H. & Day, P. R. Jr. (1998). *Developmental education: A twenty-first century social and economic imperative*. Mission Viejo, CA: League for Innovation in the Community College and The College Board.

Morante, Edward A. (1989). Selecting tests and placing students, *Journal of Developmental Education*, *13* (2), 3.

Ramirez, G. (1997). Supplemental Instruction: The long-term effect. *Journal of Developmental Education*, *21* (1), 61-70.

Rettinger, D. & Palmer, T. (1996). Lessons learned from using Supplemental Instruction: Adapting instructional methods for practical applications. *Research & Teaching in Developmental Education*, *13* (1), 57-68.

Roueche, J. E. & Baker, G. (1986). *College Responses to Low Achieving Students*. Washington, DC: The Community College Press.

3. <u>Perspectives of a Veteran Developmental Math Instructor</u> by David Moon, Eastern Shore Community College
The following thoughts are the result of 35 years of teaching developmental mathematics in the Virginia Community College System.

1. The instructor must believe in what he/she is doing and in the students' ability to accomplish the goal of graduating from college. Belief is slow in becoming a reality, but when the number of students who started in developmental courses is counted at graduation, the positive feedback helps. Often at Eastern Shore Community College (ESCC), over half of the honor society started in developmental studies. Seeing a former student become a lawyer or doctor also boosts the instructor's belief in how the community college system helps individuals fulfill their American dream.

2. Developmental math courses are only a small part of the students' success. There must be support from the administration and small class size is a must. ESCC is funded at 16 students, but classes are held with as few as 10 students. Maximum enrollment is 18 with the expectation that two students will drop in the first few weeks.

3. Developmental reading and English courses also contribute to success in mathematics and college. "Best Practices" are a package, not just mathematics practices. Support services are also part of the package. ESCC provides tutoring and opens GED classes to developmental students to compliment class instruction with additional explanation and homework assistance.

4. The in-class experience should be supportive and non-judgmental. By using the first 10-15 minutes for presenting material and the remainder of the class for student work and individual instruction, students can begin each assignment in an environment of help. Success comes from working math problems.

5. At ESCC, when a student misses class or fails to turn in homework, a report goes to counselors who follow up.

6. Homework and quizzes are graded on a scale of 1-10. For a grade of 6 or less, students have the opportunity to rework the assignment for a grade of up to 9. An exceptionally good paper is rewarded with extra points.

7. In the developmental algebra course, an average of 80% exempts students from the final exam. Students with an average below 80 must pass the instructor's final exam or the college-wide test to exit the course. There is no course average in the arithmetic course. Students must pass the instructor's final or the college-wide test to exit.

8. There is a base of knowledge that students are expected to know by memory. They must learn the vocabulary, units of measure, order of operation rules, rules of exponents, etc. in order to progress through each developmental math course.

9. At ESCC, the placement of all entering students is based upon a college-wide computerized test. On the first day of class, they are also given a test that will serve as their exit exam; this verifies proper placement. It is important that the instructor retains the authority to reassign a student to a different class according to his/her judgment. With the prevalence of computerized testing, there is a danger that these decisions will be inappropriately made at the administrative level.

10. Developmental classes should be people-centered, not curriculum driven. Classes provide opportunities to interact with students on a personal level under the safe framework of mathematics. Long-lasting relationships can result from this interaction as we are drawn into each other's lives. After 30+ years of teaching, this instructor has not become bored teaching the same low-level material because even though the course content doesn't change, the students do. Education is not about teaching content, but teaching people!

4. Benchmarks for Measuring Developmental Education Outcomes (submitted by Linda Hunt, Marshall University)

PASS RATES IN DEVELOPMENTAL COURSES

Institution	Reading	Writing	Math
2-year public	72%	71%	66%
2-year private	NA	81%	80%
4-year public	82%	81%	71%
4-year private	84%	88%	84%
All	77%	79%	74%

Data from National Center for Educational Statistics 1996
Pass - students still in course at the end of the term that passed with A, B , C, D
Withdraw and Withdraw Passing not included, Incompletes and Withdraw Failure included

PASS RATES IN POST-DEVELOPMENTAL CURRICULUM COURSES

Developmental Reading/College Social Science	83.0%
Developmental English/College English	91.1%
Developmental Math/College Math	77.2%

Boylan and Bonham 1992
Typical National State College, Passed both Developmental and College-level course with a C or better

GRADUATION RATES FOR DEVELOPMENTAL STUDENTS

Institution	Graduation Rate
Community Colleges (4 years)	24.0%
Technical Colleges (4 years)	33.7%
Public 4-year (6 years)	28.4%
Private 4-year (6 years)	40.2%
Research Universities	48.3%

Boylan, H. R. (2000). *Evaluation and Assessment of Developmental Education Programs.* Kellogg Institute 2000, Boone, NC, July 2000.

5. Additional resources

- Boylan, H. R. (2002). *What works: Research-based best practices in developmental education.* Boone, NC: National Center for Developmental Education. (For information: (828) 262-3058 or www.ncde@appstate.edu)
- Jur, Barbara (1998, Fall). Developmental course work and student success. *Michigan Community College Journal*, *4*, 2.
- National Council of Teachers of Mathematics. (1991). *Professional Standards for teaching mathematics.* Reston, VA: Author.

Placement

The continual evolution of placement policies at colleges across the country suggests that the placement issue is more complex than first appears. A cursory view would suggest that students can be accurately placed into the proper classes simply by testing their pre-algebra and algebra skills, and enrolling them in the most appropriate class based upon the results of that testing. However, placement affects not only whether students end up at the right level of study, but also the overall composition of classes and the resulting viability of employing different methods of instruction in any particular class. In developmental math, the placement process should accomplish at least two primary goals -- it should match students' math skills with course offerings and it should guarantee a reasonable degree of homogeneity in the classroom. Some colleges also use placement as a tool for matching certain types of students with certain methods of instruction.

A large variety of placement instruments is currently used to assess student skills in mathematics. These include commercial tests as varied as COMPASS, AccuPlacer, ASSET, ELM, and others, as well as state-mandated competency exams and in-house tests. (While the SAT and ACT are effectively used by some colleges to *exempt* students from placement testing, neither is designed for actual placement testing.) Whether one particular instrument is better than another depends as much upon the college as upon the test itself. Selecting an appropriate placement instrument essentially amounts to balancing various considerations including accuracy, cost, and convenience. From an academic perspective, the strongest argument for choosing accuracy over other considerations is that accurate placement ultimately affects retention. At many colleges, however, other considerations are also critical making placement dilemmas somewhat unavoidable.

In addition to matching students' math skills with course offerings, the placement process should also create a reasonable degree of homogeneity in the classroom. Irrespective of what placement scores may suggest about the skill levels of various students, too much disparity in student backgrounds or ability levels creates an environmental problem for the instructor. For example, mixing students who have never taken algebra with those who have had several years of algebra (even when placement scores are comparable) can lead to classroom management problems. There is a limit to an instructor's ability to meet the diverse needs of vastly disparate groups of students locked together in the same classroom. Consequently, factors such as prior mathematics background should also be taken into consideration.

Two additional aspects of placement include preparing students for the placement process and transfer considerations. How accurate can the results of placement testing be if students are given no opportunity to prepare themselves? Common sense suggests that students should be notified in advance of what the placement process is, how it works, and how they can prepare for it. Some colleges provide study materials and a sample exam. As for transfer considerations, a substantial gap can exist between students entering a course through placement and those entering by transfer of credits from another institution. At times, testing may be called for even when prerequisite course work has been completed elsewhere if there is not close linkage between what is taught at one institution as compared to another.

Best Practices in Placement

1. Multi-faceted Placement by Susan McClory, San Jose State University

The placement program at San Jose State University (SJSU) has several elements which distinguish it from most other programs. Students at California State Universities are required by state mandate to complete developmental course work within their first two semesters of study. SJSU has responded to this mandate by developing a single course curriculum that is offered in four different instructional formats. Through a multi-faceted placement process, SJSU not only determines developmental needs, but also matches students to different instructional formats according to ability level.

Initially, the university uses ACT scores to exempt qualified students from mandatory placement testing. Students who are not exempt take the ELM placement test administered by ETS. Following testing, the lowest two-thirds of the students are enrolled in a two-semester developmental algebra sequence, while the upper third is placed into a course that covers the same material in a single semester. Within the lower group there are two instructional formats. The lowest quartile of students meets four days per week in classes of no more than 25; the rest of the lower group meets two days per week in lecture classes (200 students) and two days per week in discussion groups (25 students). The upper third of students meets three days per week in lecture classes and two days per week in discussion groups, but covers the material in half the time. The top 10% of students are also given the option of completing the course work by independent study.

In sum, the SJSU placement process identifies student skill levels, creates relatively homogeneous groups of students based upon those skill levels, and tailors different instructional formats to different groups of students.

2. Revising Placement Practices by Thomas Armington, Felician College (based on an interview with Jamal Shahin, Montclair State University)

For colleges considering changes in current placement practices, Montclair State University provides an example of well-designed revision process. Over the past six or seven years, the university has undertaken a revision of its placement policies, a process which has involved extensive tracking of students through developmental and college-level course work. As with many New Jersey state universities, Montclair had been using a state-developed placement instrument, the New Jersey College Basic Skills Placement Test. However, data on the performance of students enrolled in the various levels of mathematics suggested that this instrument was not functioning as effectively as the university desired. To rectify the problem, the Mathematics Department began administering Readiness Tests on the first day of class. Students unable to perform satisfactorily on these tests were required to change to a more appropriate course.

Over a period of several years, the Readiness Tests were revised until it was determined that the tests accurately measured the prerequisite skills necessary for success at each level of course work. Once these tests were functioning effectively, the university began the next step of assimilating the various tests into a single, university-wide placement test to be administered prior to the enrollment of new students. The effectiveness of that test, which is currently in use, has been substantiated by the ongoing collection of data on student success rates.

Another feature of the university's placement program involves informing students about the placement process itself and assisting them in preparing for placement testing. Students are notified in advance of how the process works and are provided with study materials as well as a sample exam.

There are several noteworthy aspects of the revision process undertaken by Montclair State University. First, decisions were based on data obtained from tracking student success over time. Second, mathematics faculty were closely involved in determining whether students were being properly placed into mathematics courses as well as in the selection of an appropriate placement instrument. Third, emphasis was placed on assisting students by helping them prepare for placement testing. And finally, the university continues to monitor the effectiveness of its placement program through ongoing data collection. These components serve to assure a high degree of effectiveness in the placement process.

Teaching Techniques and Methodologies

It is readily apparent that there are many variations in how developmental mathematics is taught. Some of these are outlined below. It is hoped that readers who are using other methodologies will contribute descriptions of their instructional formats to future publications of this material.

Traditional Classroom Presentations: While many colleges employ a variety of instructional models, traditional methodologies remain the most widely used. Traditional methodologies emphasize instructor presentations of course material through lecture and demonstration of concepts. Typically these include chalkboard, markerboard, or overhead presentations. They may also include the limited use of technologies such as PowerPoint or graphing calculator demonstrations, and may involve varying degrees of student response and participation. While there are many variations in delivery styles, the primary emphasis is on instructor presentation of course material in a traditional classroom format. Class sizes typically vary from as few as 8-10 students to as many as 200.

Lab Instruction: Variations of lab instruction are also widely used. In a general sense, lab instruction emphasizes student work rather than instructor presentation during class. Some lab classes involve students working individually through assignments, workbooks, or computer tutorials while the instructor provides assistance as needed. Other lab classes emphasize small group learning in which the instructor acts as a facilitator while the class works collectively through course concepts. While delivery styles may vary, primary emphasis is placed upon students working while the instructor assists or facilitates learning. A second, common component of lab instruction involves *self-paced learning*. As students are responsible for working through course materials themselves, they are often given the flexibility to do so at their own pace. Most colleges that employ self-paced learning set a schedule of deadlines for the completion of specific material over the course of a semester, effectively establishing a minimum pace.

Lecture/Lab hybrids: Hybrid models of instruction are also in common use. As indicated by the name, these involve some combination of the traditional and lab models of instruction. One form of hybrid is found within a traditional class structure when instructors use part of the class period for presentation of course concepts and part of the period for student work. A second form is found in courses that require weekly attendance at separate lecture and lab sessions. Yet other hybrid models involve optional lab classes offered in conjunction with traditional lecture classes or lab classes that are mandatory only for low-performing students.

Calculator-based learning: An outgrowth of the reform movement of the 1990s, calculator-based learning emphasizes the use of graphing calculators as a primary learning tool for understanding mathematical concepts, especially in algebra. In most calculator-based learning models, the students are required to purchase (or borrow) their own calculator which is used daily in class. One of the primary strengths of this instructional model is that the use of graphing calculators facilitates multiple representations of mathematical concepts through the algorithmic, tabular, and graphical features of the calculator itself. A second strength is that it is a hands-on, active-learning model -- students perform most operations on their own calculators. Advocates of this model also suggest that using the calculator to perform the mechanical steps of problem solving allows for more focus on the meaning of results rather than simply on the process of obtaining them. At some institutions, calculator-based learning is also employed in the sciences and involves the use of other hand held, data-collection equipment. At such colleges, calculator-based learning is a natural fit for developmental mathematics. For those interested in learning more about the use of graphing calculators as an instructional tool, there are numerous organizations that provide training in this area. Some of these are listed on page 15.

Online Instruction: Perhaps the newest model of instruction is Internet-based or online instruction. Although still in its infancy, this instructional model is developing rapidly. Online courses are appearing and evolving as fast as colleges can produce them. In general, these courses use traditional or self-paced models of instruction that have been adapted for electronic dissemination. However, they also incorporate "chat," "blackboard," and e-mail components, as well as tutorial web sites. While some degree of personal contact is usually necessary for orientation and testing, attendance requirements are minimized and often involve the use of proctors at satellite locations rather than actual college visits.

Activity-based learning: Studies in learning styles have shown that different students learn through different sensory modalities. Some students tend to be visual learners, some tend to be auditory learners, yet others tend to be kinesthetic or "hands-on" learners. In an effort to meet the needs of kinesthetic learners, some instructors have incorporated hands-on activities into their developmental math classes. Examples of these include data collection and analysis activities, and the use of manipulatives for modeling mathematical concepts. These activities are usually conducted in groups involving a collaborative learning component. In some cases, they may also involve the use of graphing calculators.

Best Practices in Teaching Techniques and Methodologies

1. Creating and Teaching Online Mathematics Courses by Mary S. Hall, Georgia Perimeter College

As colleges try to reach more students, they turn to creating online courses which can attract many students who would not otherwise be able to take college course work. However, online courses must be equal to the regular classes both in content and evaluation, and must have the support of the faculty and administration. Assuming the support of the administration, the faculty are usually supportive if the content and evaluation methods are in keeping with college standards.

Setting up an online course is time consuming. There are three basic components -- information, communication, and testing. Information includes creation of the syllabus, forms, student releases, class notes and study sheets. It also includes homework problems, projects, handouts and book assignments. Think about all the information given in the classroom that has to be conveyed in writing.

Communication includes telephone, e-mail, fax, instant messages, bulletin boards and chat rooms. For consistency, Georgia Perimeter College uses Web CT for chat and bulletin boards. Students are encouraged to interact through the bulletin board, chat, or by phone, or they may get together for study sessions with other students who live close to them. Of course, there are designated times for the bulletin board and chat periods during which the instructor is also available..

Testing takes place in various forms. Quizzes and take-home tests are posted online or faxed to students who then fax them back complete with all work. Tests and final exams are given in proctored situations. They may be taken at different campuses, a local high school, or a library. The main thing is that the test is given to the person taking the course, which requires a photo ID. In addition, the person administering the test must be a reliable proctor.

It takes a special type of student to take an online course. Personal discipline and self-motivation are essential. Besides having the necessary computer equipment, the student must be a self-starter and must be willing to correspond twice weekly for attendance purposes.

Though these courses are in their infancy now, it appears that both learning support and academic courses will have a completion rate of 50-65%. This is in keeping with the college as a whole.

2. Keeping Students Connected to Your Online Course by Dr. Marva S. Lucas, Dr. Nancy J. O'Brien, and Scott N. McDaniel, Middle Tennessee State University

In an effort to make higher education more accessible, institutions are developing and offering online courses. These courses are attractive to many students because of the flexibility they offer. As developmental education classes are becoming available online via the Internet, educators that have taught these courses agree that student retention is becoming a concern. Instructors are forced to examine strategies that will keep students connected to their online courses.

Procedures to promote retention and success start long before class actually "meets." Therefore, selective enrollment is one key strategy that is utilized. This includes requiring students to be enrolled only by permission of the department. Students are screened to determine if they have the academic prerequisites, the equipment, the technological skills, and the time to be successful in an online class. Other strategies include an orientation meeting designed to acquaint students with the technological components of the course, the avenues for effective communication with and between students, and the measurements used for assessment.

3. Algebra Activities for Kinesthetic Learners by Anita Hughes, Big Bend Community College

A group of 20 of the worst math students was assembled and efforts were made to find effective methods of teaching them algebra. The following are some examples of activities found to be successful with these students.

To simplify a square root, the instructor began with a collection of objects, some of which were alike, in a plastic zip bag. The bag represented the radical itself, which can be seen as a container. If the bag had two identical objects, the pair was taken out putting one object on one piece of paper and the other on another piece of paper. Everything left in the bag stayed under the radical sign.

To distinguish factors and terms, the instructor gave students scissors and strips of paper with polynomials typed on them. The students were asked to cut each strip into pieces containing only one term, placing positive terms on a piece of black paper and negative terms on red paper. Students then cut terms apart into separate factors.

Like terms were modeled using red and white pipe cleaners with colored beads. Red pipe cleaners represented positive terms while white represented negative terms. One kind of bead was x, another was y. Students modeled terms such as $xyyxyyxx$, then discussed the purpose of exponents. Many other such activities were also used.

4. A Hands-on Approach to Slope by Connie Rose, South Louisiana Community College

Slope is a rate of change, not a formula to be memorized. This concept can be understood by kinesthetic and visual learners using a concrete model, a set of stairs, to illustrate steepness. To climb stairs, one steps up before stepping forward. Since slope is a rate or ratio usually written in fractional form, the numerator (vertical change - stepping up) is written first followed by the denominator (horizontal change - stepping forward). By color-coordinating the links used to build the stairs, students can easily count the blocks rising and the blocks across. To reinforce the concept, students make their own set of stairs given a certain slope.

Rulers are used as ramps to demonstrate the steepness of each set of stairs. The sets of stairs are arranged in order according to steepness of the ramp. The numerical slope values are written on the board in corresponding order. Students observe that the slopes are ordered from largest to smallest and make the connection that the larger the slope, the steeper the ramp.

The approach then moves to graphs on the coordinate plane and an input-output table. On the graphs, slope is determined by counting vertical spaces compared to horizontal spaces moving from one point to another on a line. The idea of counting is carried from the concrete model of stairs to the picture of the line. Points on the line are matched to data entries in the table. Slope is then calculated by finding the change in output as compared to the change in input.

5. An Alternate Approach to Solving Quadratic Equations by Josette Ahlering, Central Missouri State University

The general pedagogical approach to solving quadratic equations by factoring has been very linear. Students first learn to factor polynomials and then learn to solve quadratic equations. This method is efficient and effective. However, research conducted on this topic supports another approach (Ahlering, 2000). Students are shown how to solve quadratic equations when the first factoring technique is introduced. After each subsequent method is introduced, students solve equations and application problems using that particular factoring technique. By adding the solution technique early, application problems can be incorporated into lessons right away. This approach allows the students more time to practice solving and gain a better understanding of how multiple answers may or may not fit into the problem. By the close of the unit, students are proficient problem solvers and understand the need for factoring. Research comparing this approach to the more traditional approach (Ahlering, 2000) found no significant difference in final test scores for students. However, the approach took fewer days. The researcher did not add extra material to fill the available time, but felt that scores would have been higher for students in the experimental group if they had used the additional time for practice.

Using this method does not require new material, but does require reorganizing traditional material or adopting a text that uses the approach. Should this method be adopted with a text that uses the traditional method, the instructor would need to identify each equation and word problem in the section on quadratic equations with the appropriate factoring method(s). Then it is a matter of adding specific problems from these pages to each assignment as students practice the particular method taught. A few problems of each type should be reserved for comprehensive review at the end of the unit. Word problems or equations can also be derived from test banks for student practice.

Ahlering, J. (2000, March). Is sequencing of topics important? NADE National Conference, Biloxi, MS.

6. Implementation Models for Interactive Multimedia Software by D. Patrick Kinney, Wisconsin Indianhead Technical College

Interactive multimedia software is being incorporated into a variety of models to deliver developmental mathematics instruction. The software a) provides thorough explanations of concepts and skills using multimedia, b) imbeds items requiring student interaction within the instruction, c) provides immediate feedback, including detailed solutions, and d) includes provisions for the development of skills. Four implementation models for incorporating interactive multimedia software are the following:

1. *Full implementation model*. Students meet in a computer lab and follow a set schedule. The software presents the content while the instructor provides individual assistance.

2. *Hybrid model*. During the direct instruction part of class, the instructor may answer homework questions or lead whole class discussions. During the computer-mediated component, students work with the software to learn new content.

3. *Open labs supported by instructional staff*. Students use an open lab at times that best fit their schedule. The open lab allows them to use the software, ask questions, and take exams.

4. *Distance learning*. In this model, the interactive multimedia software provides the presentation of content, practice with skills, and feedback. A web platform, such as WebCT or Blackboard, is used to facilitate communication, but not as a mechanism for the instructor to present lessons.

7. Resources for using graphing calculators

- Teachers Teaching with Technology T^3
  (817) 272-5828
  t-cubed@ti.com
  www.ti.com/calc/docs/t3.htm

- TI-CARES Educational Support Programs
  (Publication describing Texas Instruments Support Programs for users of TI Graphing Calculators)
  (800) TI-CARES
  ti.cares@ti.com

- A Calculator Comparison Guide by Kay Haralson, Nancy Matthews, and Loretta Griffy, Austin Peay State University. Available on the web at <www.apsu.edu/matthewsn/calculator.htm>.

8. <u>A Discovery and Calculator Exercise for Rules of Exponents</u> by Roberta Lacefield, Waycross College

The exercise below can be used as an in-class activity or can be assigned for homework. It can be performed individually, in small groups, or with an entire class. Each approach has its advantages and disadvantages. The exercise itself is designed for the following purposes:

1) to give students experience in using the calculator to calculate roots and powers by requiring the use of

   a. appropriate grouping symbols for bases and exponents
   b. root keys
   c. power keys
   d. calculator conversion to a fraction
   e. interpreting error messages

2) to lead students to discovery of the following rules of exponents

   a. $x^{1/2} = \sqrt{x}$ and $x^{1/3} = \sqrt[3]{x}$
   b. x^{-2} and $-x^2$ are additive inverses, but x^2 and x^{-2} are multiplicative inverses
   c. $x^0 = 1$ for $x \neq 0$
   d. $x^1 = x$
   e. when the base/radicand is negative, $x^{1/2}$ and $\sqrt{x}$ are nonreal

3) to help students understand that rules in mathematics are concise descriptions of patterns and that exceptions to the argument/domain reflect deviations from the pattern.

Students fill in the table below one row at a time. Once the table has been completed, they are asked to describe the patterns they see. As rules are described, they are written and kept as a class reference. If a pattern has an entry that is an anomaly or contains an error message, the class discusses whether it was an error in the calculator entry or a restriction on the domain. The exercise challenges students of all levels. When asked to identify patterns, most students can find something. Some patterns are relatively simple, while others are complicated and lead to opportunities for exploration. The students are often surprised at the number of patterns and that the patterns reflect rules learned. The chart helps them move from concrete to the abstract.

Directions: Use your calculator to find the values. Write the result in the appropriate box. If your calculator displays an error message, write in the type of error. If your answer is a decimal, convert it to a fraction. If it is irrational, round to the thousandths place.

x	x^1	x^0	x^2	x^{-2}	$-x^2$	$x^{1/2}$	$\sqrt{x}$	$x^{1/3}$	$\sqrt[3]{x}$
0									
1/4									
1/8									
1/64									
1									
2									
4									
27									
−1/4									
−1/8									
−1									
−4									

9. Bouncing Ball Experiment by Roberta Lacefield, Waycross College

The exercise below is a data collection and analysis activity. It can be used to explore concepts related to graphing linear relationships. The objectives are gathering and organizing data, determining independent and dependent variables, and determining rate of change.

Initial height	Rebound	Rebound	Rebound	Average Rebound	(x,y)	Rebound rate $\Delta x/\Delta y$
0	0	0	0	0	(0,0)	

DIRECTIONS

Part 1: Collecting the Data

1. Use a yardstick to pre-measure and mark a height from which you will drop a ball. Record the height in the first column of the table. This is called the *initial height* because it is your starting point.
2. Ask one person to drop the ball from that height while all other group members visually identify the maximum height of the first bounce (the rebound height). Measure and record this height in the second column of the table.
3. Drop the ball two more times from that same height. Record the rebound heights in the third and fourth columns.
4. Pre-measure and mark a new initial height that is not close to the previous one. Repeat the steps above.
5. Continue until you have at least four different heights.
6. Use your calculator to calculate the average rebound. Fill in the fifth column with your averages. Discussion: Why do we repeat the rebound experiment instead of just taking the first result? Should the average be rounded?

Part 2: Graphing the Data by Hand

1. The pairs of data to be graphed are the *initial height* and the *average rebound*. The two parts of a pair of data are the independent (x) and dependent (y) variables. Since the _______________ depends on the ______________, we will call ______________ the x values and _______________ the y values.
2. Determine the scale for each set of data. Discussion: Will negative numbers be included? Will all quadrants be needed? Is there enough space to use consecutive integers or will the scale need to be changed? What is the largest number to be included? Why is the point (0,0) already included on the table?
3. For each independent variable, determine the value of its corresponding dependent variable and fill in column six of the table. Locate these ordered pairs on the graph and plot the points.
4. Draw the line of best fit, that is, a straight line which is as close as possible to *all* the data points. It may miss some points, but all points should be close. Estimate the slope of this line, m = ______.
5. Fill in the last column of the table. Convert each rate into a unit rate. Discussion: Describe what the rebound rates mean. Compare the unit rebound rates to the slope of the line. Is there a pattern?

Part 3: Graphing the Data Using a Calculator

1. Using the <STAT> feature, enter the information to be graphed. Put the information from column 1 into the table under L1. Put the information from column 5 into the table under L2.
2. Turn on the STAT PLOTS 1.
3. Use the <WINDOW> feature to set up the x and y scales. Type in the same values as used when graphing by hand.
4. Use the <GRAPH> feature to draw the graph. Does it look like the one you did by hand?
5. Follow your teacher's instructions to have the calculator draw the line of best fit and determine the equation of the line.

Innovation and Reform

Innovation and reform are taking place in many different aspects of developmental mathematics, including instruction, assessment, curriculum, and others. Innovation tends to be a continuous and ongoing product of the creative efforts of individuals who are seeking to improve the experiences of their own students, and does not necessarily imply reform. Reform, on the other hand, suggests substantive change in fundamental aspects of developmental math education. Much of the early impetus for reform came out of the joint efforts of organizations such as the National Council of Teachers of Mathematics (NCTM) and the American Mathematical Association of Two-Year Colleges (AMATYC) during the late 1980s and early 1990s. Standards developed by these groups called for greater focus on conceptual problem-solving, linkage between related concepts, the use of technology in the classroom, collaborative learning, and increased mathematical communication. While the practices described below are innovative, they may or may not be viewed as part of a reform effort depending upon how they are incorporated into a particular developmental program.

Capstone Problems: In its fullest sense, a capstone problem is a real-world problem that encompasses a full range of the mathematical concepts covered in a particular chapter or unit of study. Capstone problems are used for comprehensive review of concepts, as well as for linking individual concepts to one another. Capstone problems also link skills learned in the classroom to real-world applications of mathematical principles. For example, a set of linear data is given which represents the relationship between the temperature and volume of a known gas. The students are asked to draw a graph of the data, identify x and y intercepts, find the slope, and write the equation of the line. They are then asked to use their results to describe the relationship shown by the graph, explain the meaning of the slope and intercepts within the context of that relationship, and predict gas volumes at given temperatures from the equation of the line. Other concepts that might be discussed include independent and dependent variables, domain and range, and tabular representations of the data. Thus, from beginning to end the problem provides a comprehensive review of concepts related to graphing linear relationships while also linking the various concepts to one another and the topic itself to the real world. The strength of a capstone activity is its effectiveness in drawing together a full range of concepts into a single problem and in connecting mathematical concepts and terminology to an everyday example with which students can identify. Capstone activities also emphasize the importance of active learning, visualization of concepts, and discussion.

Collaborative Activities: Student collaboration in developmental mathematics is done in many different ways. In some classrooms, collaborative learning is the primary instructional model. Small groups of students are given comprehensive problems that can be solved in multiple ways and are asked to find a solution by any means they can justify. The instructor facilitates as each group collectively works its way through the problems. Collaboration is also common is classrooms where activity-based learning is employed (see page 13). Collaborative activities often involve some form of data collection followed by the development of mathematical concepts through performing calculations on the data collected. Another type of collaboration involves math projects completed by students in groups.

Curricular Enhancements: Curricular enhancements are modifications that add new life to traditional curricular materials by making standard concepts more interesting or meaningful to students. Examples include linking developmental math topics to courses that students will take in other fields, drawing on areas of general student interest for application problems, providing “challenge problems” for stronger students, and emphasizing the intrigue of certain types of mathematical problem solving. There are many natural links between developmental mathematics and other fields of study, particularly in the sciences, business, and economics. Instructors commonly enhance their course curricula by drawing problems directly from general studies courses in those fields. Application problems of general interest to students can be drawn from such areas as consumer affairs, social and economic trends, and the laws of nature. Mathematical intrigue can be often found in simple principles such as those underlying the Y2K or divide-by-zero dilemmas.

Multimedia Technology: With the explosion of the such technologies as PCs, Smart Classrooms, the Internet, graphing calculators, and other hand-held computer systems, there is no end in sight to the technological innovation that is revolutionizing the developmental mathematics classroom. There is a great need for pioneers in the use of classroom technology to share their techniques and discoveries with the larger community of developmental mathematics educators.

Writing in Mathematics: Developmental math instructors have incorporated various forms of writing into their mathematics courses. One example is the use of mathematics journals in which students verbally explain their reasoning and steps when solving specific mathematical problems. Journals have also been used to record students' thoughts about strategies for succeeding in mathematics or their personal experiences with math. Other types of writing include math projects or the use of essay questions on tests. Some math projects involve solving a comprehensive real-world problem, explaining the steps in the solution, and interpreting the results in a meaningful way. Others involve researching a specific mathematical topic related to the course curriculum. Essay questions on tests compel students to verbalize their reasoning about mathematical concepts.

Alternate Forms of Assessment: Although paper-and-pencil, objective testing has dominated the assessment aspect of developmental mathematics, it is not the only form of assessment in use. A growing number of instructors are using math projects, papers, or journals to supplement traditional types of testing. In addition, learning specialists have advocated alternate modes such as oral testing or testing at the blackboard for students with certain types of perceptual disabilities, even when objective questions are used. At higher levels of mathematics, the idea of portfolio assessment is gaining support with some colleges requiring math majors to assemble portfolios of tests, proofs, written projects, and presentations prior to graduation. While a portfolio of this type does not necessarily fit the assessment scheme of a single course, it does demonstrate the viability of using different types of assessments for evaluating overall student performance.

Best Practices in Innovation and Reform

1. <u>Patterns and Connections in Developmental Algebra</u> by Pat McKeague, XYZ textbooks

Instead of seeing courses as a list of many unrelated topics, instructors can teach students to see mathematical topics as parts of a branching tree of patterns and procedures. Relationships are found even in items that initially seem unrelated. Simple sequences can be used to get students started recognizing patterns. These sequences can also be used to demonstrate inductive reasoning. From there, connections between sequences are examined, moving on to two dimensional patterns and fractals. One such journey passes through Pascal's triangle, the Fibonacci sequence, and the Sierpinski triangle, ending with a surprising connection between chaotic functions and fractals.

By presenting courses this way, instructors can share with their students the things that drew them to mathematics in the first place. In addition to achieving higher level skills in algebra and critical thinking, students leave the class with an intuitive idea of the structure and beauty of mathematics.

2. Reforming the Developmental Mathematics Classroom by Dr. Selina Vasquez, Southwest Texas State University

Mathematics education reform efforts began over ten years ago and many attempts have been made to alter mathematics curriculum and instruction in grades K-12. In an attempt to make a parallel effort in developmental mathematics education, Southwest Texas State University (SWT) implemented a program called “M. Y. Math Project -- Making Your Mathematics: Knowing When and How to Use It.” The goals of this program are (1) to foster fundamental and problem-solving skills by helping students learn when and how to create and use algorithms and (2) to provide on-the-job training for developmental mathematics instructors through a framework that requires them to develop and incorporate non-traditional instructional techniques. Through the evaluation of this program, the following ten key ingredients to a successful developmental mathematics classroom were identified.

1) *Provide formal training for the instructors.* Typically, developmental mathematics instructors are drawn from a pool of part-time faculty or graduate students that have not received any formal training or have no experience in teaching. Yet, according to Boylan (1998), the education provided to developmental students should be based on a combination of theoretical approaches drawn from cognitive and developmental psychology. Instructors have to learn about these theoretical approaches and practice implementing them in order to provide effective developmental instruction. At SWT, developmental mathematics instructors undergo a three-day training prior to each semester. The training consists of an orientation to the program, lesson demonstrations, practice sessions, and workshops on “wise practice” topics such as collaborative learning, learning styles, and multiculturalism. According to surveys administered after the training, participants claim that the demonstrations had the most impact because they provided an opportunity to see first-hand how non-traditional techniques are utilized effectively.

2) *Offer a curriculum a curriculum that includes both fundamental and problem-solving skills, not simply a review.* Developmental students need a strong mathematical foundation for obtaining their educational goals since most degree plans require at least one non-remedial mathematics course. In Texas, state-mandated problem-solving tests must also be mastered in order to graduate from college. In addition, a basic-skills-only curriculum goes hand-in-hand with traditional instruction. The tendency is that one teaches the way one was taught and for the vast majority of people, fundamental skills were presented in a lecture as step-by-step procedures reinforced by drill and practice. Proponents of traditional instruction purport that this is the most effective means for gaining fundamental skills. Actual practice does not validate this theory. At SWT, traditional instruction is not as effective as non-traditional instruction when it comes to success in subsequent mathematics courses. Over 50% of students passing traditional Intermediate Algebra received a D or F in their subsequent mathematics course, whereas over 60% of students passing non-traditional Intermediate Algebra received a C or better in their subsequent mathematics course.

3) *Utilize technology for the sake of content.* Pre-algebra usually includes a significant portion of arithmetic and geometry, thus it may be difficult to find non-routine uses for graphing calculators. Therefore, some instructors are strongly against the use of any calculator. There are instances, however, when the calculator may play a significant role in the conceptual understanding of fundamental skills being taught. Even when the content is more conducive to the use of technology, precautions should be made to avoid situations where students are only using technology to verify arithmetic computations or where instructors are only using it for demonstration purposes. At SWT, technology usage is carefully integrated into the curriculum. Not every lesson contains a recommendation for technology usage, but topics that lend themselves to the use of technology do include activities, demonstrations, and/or references. Moreover, technology-related lessons incorporate guidelines for the use of technology so that the students also learn about the power of the technological tools.

4) *Base examples, activities, and problems on real-world, significant situations*. Current developmental mathematics textbook writers have accomplished this goal. Nevertheless, instructors usually draw from additional resources to develop effective lessons. The question then becomes "What resources are available?" At times, developmental mathematics curriculum is considered synonymous with K-12 curriculum. For this reason, the tendency may be to draw from these types of resources. Developmental students, however, are not K-12 students and the curriculum should reflect these differences. For instance, many developmental students are older than average and video-game type questions may not be pertinent to them. The general practice at SWT is to make connections within mathematics as well as to other disciplines. Mathematical connections assist with grounding the classroom experience in realistic uses of mathematics. Moreover, connecting mathematics to different content promotes the study of other disciplines and makes it less likely that irrelevant information is incorporated.

5) *Develop a community of developmental mathematics instructors*. Having a forum for communicating about issues such as instructional methods and math anxiety is important. Developmental students are perhaps the most mathematics anxious students. Miller (2002) found that most low-achieving students have mathematics anxiety. As the negativity associated with mathematics anxiety has the potential to destroy a positive learning environment, instructors need to discuss these types of situations with empathetic colleagues. The essence of community is well developed at SWT and the benefits are profound. The developmental mathematics instructors meet weekly to discuss administrative responsibilities as well as the logistics of classroom management. Although weekly meetings provide an opportunity to demonstrate and share lessons, the instructors frequently discuss lessons and day-to-day events on an informal basis as well.

6) *Student performance should be evaluated constantly and using various assessment tools*. Developmental mathematics students need several opportunities to demonstrate that they understand the content. Both formal and informal evaluation should take place. Instructors should provide students with well-sequenced problems that focus on problem solving as well as basic skills. Students at SWT are given daily homework, weekly quizzes, at least four exams, and one final exam. Since the SWT program focuses on creating algorithms, this activity is reinforced in the assessment tools. That is, the students are asked not only to solve real-world problems, but also to describe how they solved them.

7) *Utilize various instructional techniques*. Developmental mathematics students have not been successful in the past and thus the instructional techniques used in the past should not be replicated. Instead, instructors need to undo misunderstandings and build conceptual comprehension. This can be done by engaging students in discovering the how's and why's in mathematics which requires using non-traditional instructional techniques. The M. Y. Math Project is based on an instructional method that consists of a steady progression through four phases: modeling, practice, transition, and independence. 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 understanding of mathematical concepts by creating pertinent algorithms using problem-solving techniques which are solidified through carefully developed, real-world problems.

8) *Make efforts to build confidence*. As noted above, developmental mathematics students have not been successful in the past. This may be primarily because they tried to memorize procedures. Consequently, motivation may be low and efforts may be weak. By focusing on understanding how and why a process works, students are more likely to experience authentic success and develop confidence. Making use of algorithms helps to relieve the social and emotional problems of many of these students (Boylan, 1998). One such problem is mathematics anxiety. Algorithms provide structure to problems; if students become anxious and cannot solve a given problem, they can rely on the algorithm for support and guidance. Low self-esteem is another common characteristic of developmental mathematics students that may be relieved by the use of

algorithms. Algorithms are reliable guides to problem solving which, if developed and used correctly, result in correct solutions and conceptual understanding. As the students experience success, their confidence may increase. In addition, students may develop more enthusiasm for, and interest in, the subject and school because of this newfound positive experience. Another means by which algorithms address the social needs of students is by fostering interaction. When students are creating their own algorithms, they interact with other students to compare results, as well as with the teacher for logical accuracy. This, in turn, produces ties among the students, the teacher, and the school. These improvements on the social and emotional inadequacies of the developmental mathematics student will potentially increase retention in mathematics classes and college in general.

9) *Be sure that developmental mathematics courses are aligned with the goals of the students, the department, and the institution.* After completing the course, the students should (1) be prepared for continued study of mathematics, (2) be equipped with the mathematical knowledge and skills needed in their respective careers, (3) have refined and strengthened mathematical knowledge and skills, and (4) have a desire for life-long mathematical learning through improved problem-solving, reasoning, and communication skills using mathematical connections, modeling, and technology. At SWT, every effort is made to provide students with a course that fits these goals.

10) *Everyone should be having fun.* Making the developmental mathematics classroom an interactive, hands-on place to learn to "figure things out" is enjoyable to everyone. Instructors should not be afraid to take risks by facing challenging lessons and resistant students head-on.

Boylan, H. R. & Saxon, D. P. (1998). The origin, scope, and outcomes of developmental education in the 20th century. In J. L. Higbee & P. L. Dwinell (Eds.), *Developmental education: Preparing successful college students, Monograph Series #24.* (ERIC Document Reproduction Series No. ED 423794).

Miller, N. C. (2000). *Perceptions of motivation in developmental mathematics students: I would rather drill my own teeth* (Dissertation). TX. (ERIC Document Reproduction Series No. ED 457911).

3. <u>Information on the Reform Movements of the 1990s</u>

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

American Mathematical Association of Two-Year Colleges. (1995). *Crossroads in mathematics: Standards for introductory college mathematics before Calculus*. Memphis, TN: Author.

4. <u>Additional Resources</u>

Hartman, H. J. (1993). Cooperative learning approaches to mathematical problem solving. In A. S. Posamentier (Ed.) *The art of problem solving: A resource for the mathematics teacher*. Kraus International Publications.

Learning Disabilities

Learning disabilities differ substantially from developmental deficiencies. While developmental deficiencies are generally associated with academic underpreparedness, lack of motivation, poor organizational or learning skills, and the like, learning disabilities are neurological dysfunctions that affect perceptual, processing, or memory functions. Consequently, meeting the needs of students with verifiable learning disabilities is entirely different from meeting the needs of underprepared students and may require professional training. Developmental math educators who lack such training should at least be informed as to how to identify potentially learning-disabled students in order to make referrals to trained professionals when necessary. Learning specialists or others who have experience in this field are invited to contribute information on this topic to future issues of this publication.

Best Practices in Learning Disabilities

Teaching Mathematics to Students with Learning Disabilities by Dr. Ruth Feigenbaum, Bergen Community College

At Bergen Community College (BCC), the number of self-disclosed students with learning disabilities has been increasing. If these students are enrolled in a degree program, they must, at a minimum, successfully complete the developmental mathematics requirement. In order to provide for the special needs and learning styles of these students, BCC offers dedicated sections of developmental mathematics and elementary algebra for LD students. The purpose of these special classes is to establish a classroom environment that promotes learning, while focusing on the specific needs and learning styles of each individual student, without compromising the content of the course and the standards of the Mathematics Department.

For most LD students, it is the learning disability not the subject matter that interferes with the learning process. In order to "level the playing field," instruction in the LD mathematics classes emphasizes techniques that allow students to circumvent their learning disabilities and focus on the learning of mathematics. To accomplish this end, individual teaching and learning strategies are developed cooperatively by the instructor and the student, techniques that focus on the student's strengths.

Modes of instruction emphasizing the proper reading and writing of mathematics are an integral part of the course. In order to work with mathematical expressions, students must be able to distinguish between the terms and the factors comprising an expression. To avoid errors in simplifying expressions, students must develop the ability to write out their work one step at a time. When working with applications, a correct reading of the words of the problem and an accurate mathematical representation of the meaning of the problem are prerequisite to solving the problem.

Many of the teaching and learning strategies developed emphasize the use of color or space. Colored pencils or pens are used to highlight items which might be visually misinterpreted, thereby minimizing copy errors and inaccurate reading. Color is also used to focus a student's attention on a particular area of weakness. The appropriate use of space can be a significant aid to the LD student. Increasing the work space by using large sheets of paper or the blackboard helps students organize their work. Limiting problems to one per page avoids distractions. Subdividing a page so that subtasks are separated from the main procedure of the problem permits students to focus on individual tasks.

Many of the problems encountered by the LD student in learning mathematics are similar to those of the general population, only more pronounced. Thus, many of the strategies used in the LD mathematics classes are applicable to all students; they are just good teaching and learning techniques.

For more information on the topic of teaching algebra to LD students, see the article *Algebra for Students with Learning Disabilities*, published in the April 2000 issue of *The Mathematics Teacher*, a publication of the National Council of Teachers of Mathematics.

Academic Support

It is well established that many students entering college with developmental needs in academic content areas also have deficiencies in study skills, classroom skills, organizational skills, and other such attributes that are critical for success in college. Historically, colleges expected students to overcome such deficits themselves. However, in recent years many institutions have taken a more active role in teaching students what might be termed "college success skills." Much of this activity occurs in the academic support areas where students seeking individualized tutorial assistance also receive instruction on how to manage their studies more effectively. Some of this activity also occurs programmatically through freshman seminars, educational opportunity programs, and the like.

At least two other types of programmatic support are also employed in developmental mathematics. This first is a well-established model known as *Supplemental Instruction* (SI), which combines characteristics of peer tutoring and small group instruction. The formal SI model targets high-risk courses rather high-risk students and is most commonly used in courses such as Calculus or Physics, which are historically difficult for all students. With some variations, however, the SI model has also been used successfully in developmental mathematics. In Supplemental Instruction, an SI leader (usually an upper class student) attends all classes for a particular section of a course and then holds 2-3 supplemental sessions per week. During these SI sessions, the leader works through course material with students in a small group context, acting as a facilitator rather than lecturer. SI also integrates learning strategies with course content by helping students effectively use their textbook, understand terminology, develop study strategies, and prepare for tests. By inviting and encouraging all students to attend, rather than only those whose performance is low, SI attempts to foster a non-remedial environment as well.

One variation of the SI model is to offer *Review Sessions* strictly prior to tests rather than 2-3 Supplemental Instruction sessions per week. This option can achieve some of the same benefits as SI, but requires a lesser time commitment on the part of the students. A second variation (see below) is the use of "linked labs" designed to be taken concurrently with a particular developmental course. This option can be of particular benefit to students who are retaking a course in that it provides regular, structured assistance that is coordinated directly with the course itself.

One deficiency of support services such as those described above is that usage is dependent upon individual student initiative. Consequently, even the best services are often underutilized. A second type of programmatic support is built into the course structure itself. The advantage of built-in support is that all students receive its benefits irrespective of individual levels of motivation or initiative. *Built-in support* usually involves in-class, curricular activities designed to improve students' learning skills such as textbook usage, note-taking practices, study strategies, ability to understand mathematical terminology, or others. Curricular activities that focus on the development of learning skills can be incorporated periodically as individual exercises or regularly through the use of supplemental materials.

Best Practices in Academic Support

1. Linked Labs: Possible Key to Success in College Algebra? by Don Brown, Macon State College and Donna Saye, Georgia Southern University

In an effort to increase students' success in College Algebra, the Learning Support Department at Georgia Southern University offered a 1-hour algebra lab course for students to take concurrently with the College Algebra course. The lab provided further instruction and assistance on topics students found difficult. It was institutional policy that any student earning less than a C grade in College Algebra would be required to take the lab when re-enrolling in College Algebra.

Initially, the lab course was plagued by complaints of students and instructors. Over time, adjustments were made to lessen the complaints and make the course more beneficial to students and instructors. During the Spring Semester 2000, labs linked to the same algebra class were piloted. All of the students had previously attempted College Algebra one or more times. As a result of the linked labs, student needs were better met and more students successfully completed the class. Benefits of linking the lab to an algebra class included better opportunity for the lab instructor to communicate with the course instructor about lessons, better environment for group work since all students were from the same class, extra opportunities for students to learn to use the TI-83 calculator, and greater development of student confidence.

Data from almost 3700 students comparing student performance in the linked-lab courses to that of students in College Algebra who did not take the lab showed that approximately 53% of those taking the lab earned grades of C or better as compared to 43% of those in the traditional classes. The number of students receiving A or B grades was also higher. The students in the linked-lab algebra classes were all repeaters, none of whom had been successful in algebra in the past. It is also interesting to note that few students withdrew from the linked class. For the first time, these students felt that they had a good chance of passing.

2. Resources for training tutors (contributed by Linda Hunt, Marshall University)

<u>The Master Tutor: A Guidebook For More Effective Tutoring</u> by Ross B. MacDonald
1994
Williamsville, NY: Cambridge Stratford, Limited
Hardcover 64 pages (ISBN: 0935637206)
Softcover 124 pages (ISBN: 0935637192)

<u>The Tutor's Guide</u>
(Videotape series of fourteen, 15-minute programs with instructor's manual)
GPN
P. O. Box 80669
Lincoln, NE 68501-0669
(800) 228-4630
<gpn@unlinfo.unl.edu>

<u>A Look at Productive Tutoring Techniques</u>
(Videotape series of eight modules)
Undergraduate Tutorial Center
Box 7105
North Carolina State University
Raleigh, NC 27695
(919) 515-5619
<ken_gattis@ncsu.edu>

3. <u>Additional Resources</u>

Hart, L. & Najee-Ullah , D. (1995). *Studying for mathematics*. New York: HarperCollins College Publishers.

Smith, R. M. (1994). *Mastering mathematics: How to be a great math student.* Belmont, CA: Wadsworth Publishing Company.

A mathematics study skills guide by Neil Starr, Nova Southeastern University. Available on the web at <www.undergrad.nova.edu/AcademicServices/mathsg.html>.

Additional Resources for Developmental Mathematics Educators

1. NADE Math SPIN web site: http://www.etsu.edu/devstudy/spin

2. Graduate Programs in Developmental Education

The Kellogg Institute (offers training and certification of developmental educators)
ASU Box 32098
Appalachian State University
Boone, NC 28608-2098
(828) 262-3057
http://www.ncde.appstate.edu

Grambling State University (offers master's and doctoral degrees in Developmental Education)
Campus Box 4305
Grambling, LA 71245
(318) 274-2238

National-Louis University (offers master's degree in Developmental Studies on-campus and on-line)
30 N. LaSalle St.
Chicago, IL 60602
(888) 658-8632
http://www.nl.edu/ace

3. Professional Development

Teachers Teaching with Technology T^3
Week-long summer institutes and short courses
(Graduate credit is available)
e-mail: t-cubed@ti.com
http://www.ti.com/calc/docs/t3.htm

American Mathematical Association of Two-year Colleges
Outer Banks Summer Institute
(Graduate credit is available)
http://www.math.ohio-state.edu/shortcourse/

Technology Institute for Developmental Educators
S.W. Texas State University
San Marcos, TX
http://www.ci.swt.edu/TIDE/TIDEhome.htm

International Council on Technology in Collegiate Mathematics (ICTCM)
Professional Development Short Courses
(Graduate credit is available)
http://www.ictcm.org/shortcourses

Supplemental Instruction Supervisor Workshops
Training in implementing and supervising an SI program
e-mail: cad@umkc.edu
http://www.umkc.edu/cad/

4. Publications

Journal of Developmental Education
National Center for Developmental Education
Reich College of Education
Appalachian State University
Boone, NC 28608
http://www.ncde.appstate.edu

Research and Teaching in Developmental Education
New York College Learning Skills Association
http://www.rit.edu/~jwsldc/NYCLSA

Mathematics and Computer Education Journal
(Three upcoming special issues on developmental mathematics)
June 15, 2002: "Innovative Approaches"
January 15, 2003: "Incorporating Technology"
September 15, 2003: "Reforming Pedagogy and Instruction"

The Journal of Teaching and Learning
Ohio Association of Developmental Education
c/o Developmental Education Department
Owens Community College
P. O. Box 10,000
Toledo, OH 43699-1947
e-mail: phausmann@owens.cc.oh.us or enewman@owens.cc.oh.us

Mathematics Teacher
Journal for Research in Mathematics Education
National Council of Teachers of Mathematics
1906 Association Drive
Reston, VA 20191-1502
(800) 235-7566
orders@nctm.org

Eightysomething: Newsletter for users of TI calculators
P. O. Box 650311
M/S 3908
Dallas, TX 75265

Web Sites

American Mathematical Association of Two-Year Colleges (AMATYC): http://www.amatyc.org
National Council of Teachers of Mathematics (NCTM): http://www.nctm.org
College Reading and Learning Association (CRLA): http://www.crla.net
National College Learning Center Association (NCLCA): http://www.eiu.edu/~lrnasst/nclca/

Miscellaneous

Annotated Research Bibliography in Developmental Education
Annotated Bibliography of Major Journals in Developmental Education
For information: National Center for Developmental Education
(828) 262-3057
http://www.ced.appstate.edu/ncde

Remedial Education at Higher Education Institutions in Fall 1995
National Center for Education Statistics
Office of Education Research and Improvement
555 New Jersey Avenue NW
Washington, DC 20208-5574