AIR Association for Institutional Research

Assessment of Student Learning in College Mathematics:

Towards Improved Programs and Courses

Edited by

Bernard L. Madison

Assessment in the Disciplines

Volume 2

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THE ASSOCIATION FOR INSTITUTIONAL RESEARCH

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FOREWORD

This volume is the second in a series sponsored by the Association for Institutional Research and aimed at assessment in the disciplines. The first year, 2005, was dedicated to employing assessment in teaching business; this volume is aimed at professionals teaching mathematics and related fields. Future volumes are planned for focusing on assessment in engineering and writing among other topics.

One might well ask, why mathematics? Mathematics is one of the most basic and important subjects taught at any and all education levels. As an example, studies that I did myself many years ago showed that success in first-year chemistry at the university level was virtually unrelated to whether or not the student had studied chemistry in high school, a counter-intuitive conclusion rejected by the distinguished chemistry faculty involved despite the hard evidence presented to them. At the same time, however, one's high school classes in mathematics, and performance in those classes, were significant predictors of performance in first-year chemistry classes at that selective university. In short, mathematics was found to be the *tool* of the science of chemistry, one that was (and remains) so important to success that it is *the* significant predictor of success. Hence the study of mathematics is critically important not only for its own sake but, even more importantly in most cases, as a very important tool of success in other disciplines.

Economic competition has led to a concern in the larger society regarding education in such fields as the sciences and engineering where mathematics has been shown to be important to success. Even in business and education, knowledge of mathematics and its sister field of statistics, which is based on mathematics, is critically important to success. As a consequence, it is important to us as a society to do the best that we can to ensure that our students are getting the highest quality education possible in this most important field.

This volume is exciting because it is about how to convey one's enthusiasm about an interesting field of study even when teaching at relatively basic levels. The authors of the chapters, and in particular the editor, Bernie Madison, deserve a lot of thanks for producing fascinating insights about teaching a subject which they clearly love and how assessment can enhance that teaching. To me that is the very definition of a faculty member, *i.e.*, one who conveys the love of the subject matter in an understandable fashion. Using this definition, the volume which follows is the product of some loving sharing by very capable faculty members.

I would also like to convey a special thanks to the Association for Institutional Research, and especially the Publications Committee and the current editor of the *Resources in Institutional Research* series Rich Howard, for sponsoring this series. We in institutional research cherish our role as partners with faculty in improving higher education through assessment. This volume and series are tangible evidence of that commitment.

John A. Muffo
Ohio Board of Regents

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CHAPTER 1. INTRODUCTION TO THE VOLUME ASSESSMENT IN COLLEGE MATHEMATICS: MANY OPTIONS

Bernard L. Madison
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Introduction

The vast and varied landscape of collegiate mathematics has enormous inertia, built over a century of experience with a fairly stable offering of courses. In recent years, however, mostly during the last quarter century, innovations and reforms have overcome some of the inertia. Assessment of student learning, especially in programs or in coherent blocks of courses, is playing a major role in some of the reforms by providing evidence of improvements, identifying changes that need to be made for more improvements, or validating existing practice. Assessment is prominent in U.S. collegiate mathematics largely because it has been mandated by entities external to the mathematics faculties, but the value of assessment done right is becoming more apparent as mathematics faculties take ownership and work seriously toward improved courses and programs.

This volume presents a remarkably descriptive sample of assessment activity across U.S. mathematics in 10 case studies from nine institutions. An additional metaphorical essay gives the flavor of assessment's interaction with U.S. collegiate mathematics. The size of U.S. collegiate mathematics —over 3,000 institutions with mathematics programs—makes any comprehensive description of assessment activity untenable. However, this volume, when coupled with two previous volumes of case studies by the Mathematical Association of America (MAA) (See Box 1 and Box 2), provides a diverse and informative survey of assessment programs in collegiate mathematics (Gold, Keith, & Marion, 1999; Steen, 2006). Two features distinguish this volume from the previous MAA volumes: The case studies here are more extensive and detailed, and the assessment programs being described are more mature. The format for these case studies was free form with individual authors deciding what to report and how to report it. Nonetheless, there are common themes throughout, with the most common and overriding theme being the quest for improved courses and programs based on evidence of student learning.

Assessment of student learning across multiple courses is alien to the world of many college mathematics faculty. Circumstances in collegiate mathematics mitigate against faculty initiatives for substantial assessment programs (Madison, 2006). Yet most mathematics departments have responded to mandated assessments, and some of those have proven effective and positively productive. Two of the cases in this volume—Keene

State College (KSC, Chapter 4) and Nassau Community College (NCC, Chapter 3)—not only provide good examples of productive responses to mandates but also contain good advice for others to follow. One of the cases—Alverno College mathematics (Alverno-Math, Chapter 5)—has a subtext of a new mathematics faculty member adapting to a culture of assessment that had developed at Alverno over the previous 10–15 years. Alverno College is often cited as a model of a culture of assessment, having been engaged in a college-wide effort for three decades.

Some of the cases began and continue the quest for improvements outside the pure assessment of learning movement, measuring course effectiveness by grades, student opinions, and student retention. In all such cases, more direct measures of student performances to demonstrate learning have been or are being adopted, moving closer to the now widely accepted model of assessment for the purpose of program improvement.

Box 1
Assessment Practices in Undergraduate Mathematics

This 1999 volume contains 72 brief case studies collected during the period 1996-1998 that describe assessment activities at a wide variety of colleges and universities. Techniques offered in this book range from brief ten-minute classroom exercises and examples of alternative testing, group work and assignments, to examples of how departments may measure the placement of students into courses, the effectiveness of the major, and the quantitative literacy of their graduating students.

Bonnie Gold, Sandra Z. Keith, and William A. Marion, Editors

Mathematical Association of America
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Numerous and Varied Motivations

The reasons for seeking course and program improvements and for the wide variety of methods illustrated in these ten chapters are numerous and compelling. These reasons explain both why certain practices are followed in assessment and why assessment is complicated and restrained. Among the reasons are the following circumstances in U.S. collegiate mathematics over the past three or four decades.

- *Increasing enrollments*. Enrollments in U.S. collegiate mathematics

Box 2
Supporting Assessment in Undergraduate Mathematics

This 2006 volume contains 26 case studies offering lessons learned during a four year National Science Foundation (NSF) - supported MAA project designed to support mathematicians and mathematics departments in the increasingly important challenge of assessing student learning. Three introductory essays (by Peter Ewell, Bernard L. Madison, and Lynn Arthur Steen) set assessment in broader academic and national contexts. Case studies deal primarily with coherent blocks of courses designed for particular purposes, (*e.g.*, general education, mathematics-intensive majors, developmental education, quantitative literacy, teacher preparation, and mathematics majors). Institutions represented in the volume vary considerably in size, location, and mission.

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more than doubled in the period 1960–1990 to approximately six million per year, placing strains on departmental faculties to respond appropriately (see Figure 1). This is a major issue in several of the case studies, especially those from University of Arizona (Arizona, Chapter 11), Colorado School of Mines (CSM, Chapter 9), University of Texas at El Paso (UTEP, Chapter 10), and Virginia Commonwealth University (VCU, Chapter 6).

- *High unsuccessful rates.* Collegiate mathematics provides major challenges for many students, and unsuccessful (failure or withdrawal) rates are high at many institutions, where sometimes more than half the students in introductory courses fall into the unsuccessful category. Most institutions, especially those with large enrollments, have been seeking improvements. This has led to innovative approaches to course structures, more rigorous admission and placement processes, changes in class sizes, tutoring programs, and many other efforts. Two of the case studies in this volume—Arizona and UTEP—provide excellent examples of responses to this issue.

- *Growing and changing demands for service courses*. Most college mathematics enrollments result from course requirements for other college majors—notably, sciences, engineering, and business. The need for mathematics in these disciplines has grown and changed over the years. Almost all the cases in this volume address this issue, but four of them have it as a major theme. One of the four, relating experience at North Dakota State University and University of Wisconsin-Madison (NDSU, Chapter 2), focuses almost entirely on service courses for other disciplines. Another, from the United States Military Academy (USMA, Chapter 8), illustrates how a core mathematics program serves every undergraduate major. Two others highlight issues with engineering (CSM) or business (Arizona).

- *Articulation with K-12, including the need for remediation*. As college enrollments increased in the 1960s and 1970s, remedial or developmental mathematics courses became more numerous in colleges, especially in two-year colleges. These courses, whose content is largely arithmetic or beginning algebra, do not usually carry college degree credit yet constitute approximately one in three enrollments in college mathematics (Lutzer, Maxwell & Rodi, 2002). These and related circumstances have prompted closer coordination or articulation between K-12 mathematics and college mathematics (Madison, 2003). Two of the cases here, Arizona and NCC, address this specifically.

- *More variety of students*. As the graphs in Figure 1 and Figure 2 show, during 1950–1990, college attendance became the norm in U.S. education. This vastly increased college population, from both larger percentages of new high school graduates and returning older students, increased the variety of students who represented various learning styles and goals in college mathematics. These changes prompted the need for new courses and assessment methods as illustrated in the Alverno cases and the VCU case.

- *Need for general education courses.* Until recently, many mathematics departments' offerings were of two kinds: courses for mathematics majors and service courses for other disciplines. Students who wanted mathematics for general education usually enrolled in courses designed as service courses, but this has changed in recent years. The growing quantification of society has prompted the design of courses for general education, often under the rubric of quantitative literacy (QL). Two of the cases, VCU and Alverno College, quantitative literacy (Alverno-QL, Chapter 7) highlight how two institutions are teaching and assessing QL.

- *Growing demands for accountability*. Demands for accountability of learning productivity in higher education have been growing for 25 years. Some of these demands come from within institutions (*e.g.*, Alverno and USMA) while others come from external entities such as systems (*e.g.*, NCC) or the state (*e.g.*, KSC and Arizona). These demands for accountability are largely responsible for the prominence of assessment in collegiate mathematics. During the past 25 years calculator and computer technologies have dramatically changed the way mathematics is practiced in applications. The ready availability of powerful hand-held calculators was a major factor in promoting calculus reform in the 1990s and continues to provide impetus for investigating how to best utilize this technology in collegiate mathematics teaching and learning. Assessing learning in the presence of technology is a major component of the USMA case, and the KSC case highlights how assessment can point to weakness in students' capabilities with technology.

- *More awareness of responding in practice to learning research results.* Research on learning in mathematics has had little effect on practices in collegiate mathematics instruction. This is due in part to how little we know about how students develop mathematical capabilities and mentally construct mathematical concepts. Nonetheless, as faculties attempt to measure student learning developmentally, knowing how this learning develops becomes critically important. Aspects of this development are present in most of the cases, but more prominent in the more mature programs such as the two cases at Alverno (Alverno-QL and Alverno-Math) and at USMA.

Evolution of U.S. Collegiate Mathematics

To understand better the current environment of assessment in U.S. collegiate mathematics, it helps to consider five time periods: before 1920, 1920–1950, 1950–1975, 1975–1990, and after 1990. Before 1920, most U.S. colleges offered a classical curriculum with all students studying the same subjects during the four years. Comprehensive assessment, often using external readers, was common practice. A significant portion of the college curriculum was classical mathematics: plane, solid, and analytical geometry; plane and spherical trigonometry; and algebra. With the reform of the Harvard undergraduate curriculum led by Harvard President Charles Eliot during the latter part of the nineteenth century, majors and electives were introduced into U.S. higher education. As a response to this change, general education courses were introduced to complement the study-in-depth in the major (Steen, 2004).

Majors and electives**.** The second period roughly spans 1920–1950. During this period, collegiate mathematics offerings for non-mathematics majors were very similar to those of the classical curriculum. In fact, mathematics was essentially alone as a mainline academic discipline in not developing general education or introductory college courses. There were, however, during this period various efforts to create mathematics courses for the liberal arts. See, for example, the description by Allendorfer (1947).

Expansion

For several reasons, following World War II, U.S. mathematics expanded, a circumstance that dominated during 1950–1975. The National Science Foundation (NSF) was established in 1950. Federal programs such as the GI Bill following World War II and the National Defense Education Act enacted in 1958 following the launch of Sputnik by the Soviet Union encouraged and supported science and mathematics study in college. Applications of mathematics during the war had elevated the importance of mathematics as a practical subject in an industrial society. In addition, several non-governmental movements and developments pushed college mathematics forward. In the 1940s and 1950s the School Mathematics Study Group's development of the "new math" began, use of the College Board's SAT examination expanded, the Advanced Placement program was created, and Educational Testing Service (ETS) and American College Testing (ACT) were founded.

Mathematics study expanded because of an emphasis on mathematics-intensive majors and the increased college-going rate among U.S. students. Comprehensive assessment became unwieldy and course grades became the dominant assessment measure. As Figure 1 shows, during the 15 years 1965–1980, the number of enrollments in the fall term in college mathematics courses (two-year and four-year colleges) increased by 90%, from approximately 1.35 million to 2.57 million, leveling out at about 3 million in 1990. Since the fall term is approximately half the total annual enrollment, currently there are approximately 6 million enrollments in college mathematics courses every year (Madison & Hart, 1990: Lutzer, Maxwell, & Rodi, 2002).

This increase was analogous to the increase in the total U.S. college enrollments, which more than doubled over the period 1965–1980 from 5.3 million to 11.6 million, creating a greater variety of students, both in educational background and interests. See Figures 2 and 3 that are graphs of data from the U.S. Department of Education (Snyder, 1993).

During the period 1950–1975, mathematics departments in colleges and universities were dealing with increasing enrollments in both their undergraduate and graduate programs, some increases in courses for

Figure 1
U.S. College Fall College Mathematices Enrollments 1965-2000

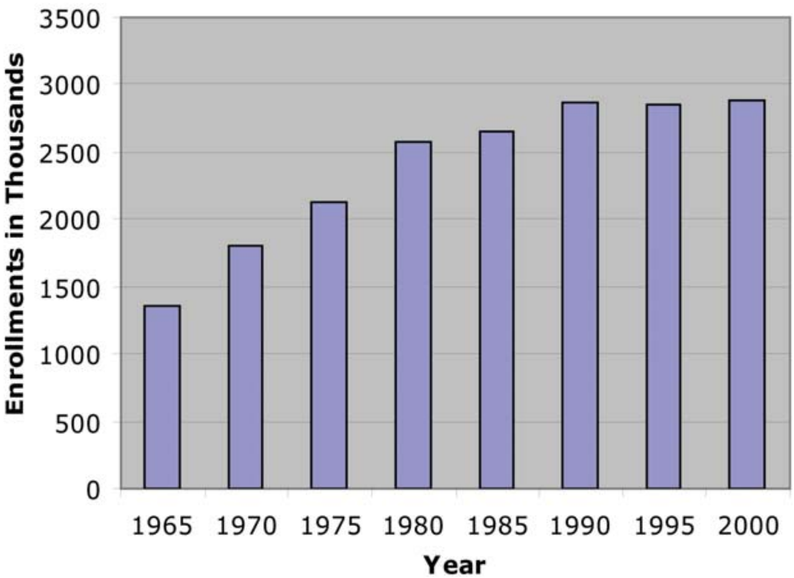


Figure 2
U.S. High School and College Enrollments and Projections, 1890–2007

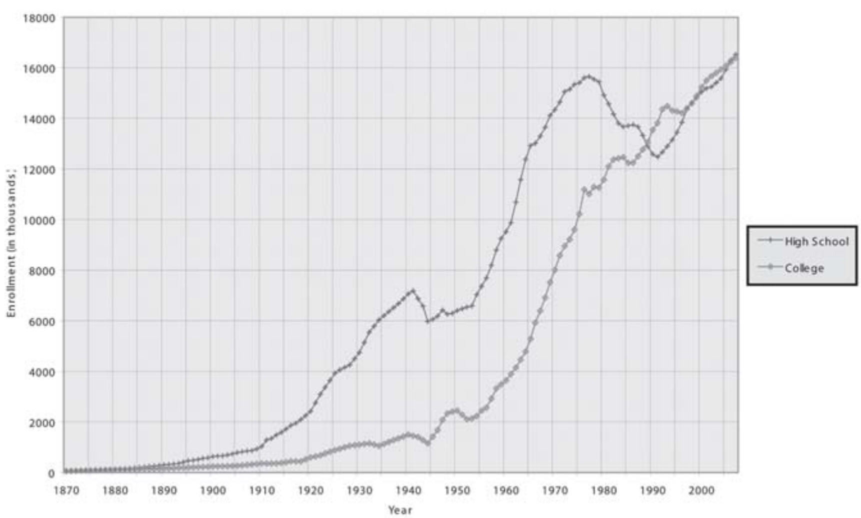
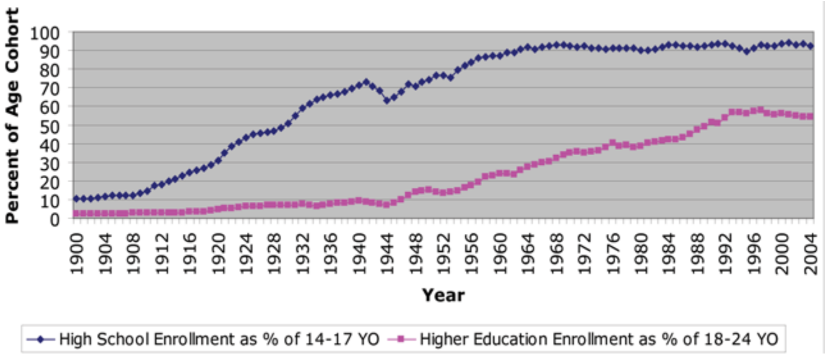


Figure 3
U.S. High School Enrollment as Percent of 14-17 Age Cohort (Top)
U.S. Higher Education Enrollment as Percent of 18-24 Age Cohort (Bottom)



mathematics majors, and larger increases in service course offerings for engineering, science, and business administration majors. Business was becoming a prominent college major and one new mathematics course appeared and now largely serves business majors. That course is called finite mathematics and was basically defined by a classic textbook, *Introduction to Finite Mathematics* by Kemeny, Snell, and Thompson (1956).

In almost every way, 1950–1975 was an expansive era for college and university mathematics. Research in mathematics blossomed, supported largely by NSF grants. The annual number of degrees in mathematics, both undergraduate and graduate, grew rapidly: bachelor’s degrees tripled from about 6,000 to 18,000, master’s degrees quadrupled from about 1,000 to 4,000, and doctoral degrees grew by about six-fold from 160 to over 1,000 (Madison & Hart, 1990).

During this period, because more students with different backgrounds entered college, mathematics departments began offering several possible entry points for incoming students. This necessitated placement schemes that assessed students’ knowledge and skills in mathematics and placed them in an appropriate course. These schemes provided many departments with early experience with multidimensional assessment. Other departments with graduate programs had been using multidimensional assessment for graduate degree programs as regular fare. See Chapter 12, *Burden of a Name*, for more on this topic.

Addressing Change

During 1975–1990, collegiate mathematics was affected by several developments, none more prominent and influential than those connected with computing. Computers and hand-held calculators became more powerful and readily available, and computer science emerged as an academic discipline, often growing from within a mathematics department. Demand for mathematics grew largely because of its importance in computer science. At the same time, mathematics departments struggled to accommodate large enrollments and an increasing variety of students. The combined pressures prompted national studies of the mathematical sciences, from entrance courses to resources for research. One such national study, Mathematical Sciences in the Year 2000 (MS2000), by the National Research Council, surveyed human and fiscal resources and curricula (Committee on the Mathematical Sciences in the Year 2000, 1991). Partly spurred by pressure from discrete mathematics, calculus was placed in the national spotlight. During the period 1985–2000 a major nationwide effort was waged, with considerable NSF support, to reform calculus, which was the most prominent college mathematics subject. Calculus reform became part of MS2000 and was kicked off nationally with a major colloquium at the National Academy of Sciences in 1987, *Calculus for a New Century* (Steen, 1987). At the same time that the mathematics community was considering reforming calculus, the pressure for reform of undergraduate education was growing (Barr & Tagg, 1995; Madison & Ganter, 2006), and the assessment movement was emerging from two efforts: to recapture coherence in the college curriculum and to evidence learning productivity for more accountability (Ewell, 2002).

In addition to the national efforts to assess the health of collegiate mathematics, significant developments were taking place in K–12 mathematics. Following the demise of new math in the late 1970s, national guidance for K–12 mathematics lagged. College and university mathematicians had become less active in K–12 curricular matters following the failure of new math and their preoccupation with the expanding needs of college teaching and research. Nonetheless, the National Council of Teachers of Mathematics (NCTM) issued in 1989 their *Curriculum and Evaluation Standards for School Mathematics* (1989). Reaction to this document prompted more intense discussions of mathematics learning, both by mathematical education specialists and mathematicians. A decade later, NCTM issued the second version of its *Standards* (2000).

Enter Assessment

In 1990, the Mathematical Association of America (MAA) created a Subcommittee on Assessment of its Committee on the Undergraduate Program in Mathematics (CUPM). In 1995, when CUPM approved the Subcommittee's guidelines, *Assessment of Student Learning for Improving the Undergraduate Major in Mathematics*, the national collegiate mathematics community officially recognized assessment. This recognition has been growing into practice, and both the MAA and the American Mathematical

Association of Two Year Colleges (AMATYC) have strongly endorsed assessment as an integral part of instructional programs in recent guideline documents (CUPM, 2004; AMATYC, 2005) while assessment was far less prominent in earlier analogous documents (CUPM, 1991; AMATYC, 1995). With NSF support, both MAA and AMATYC have carried out faculty development projects on assessment within the past five years. The MAA assessment guidelines and faculty development project are discussed in some detail in several of the cases, including NDSU, KSC, USMA, and CSM. For more detailed accounts of assessment and the collegiate mathematics community, see works by this author in this volume (*Burden of a Name,* Chapter 12) and in a volume (Box 2) growing out of the MAA's faculty development project on assessment (Madison, 2006).

Options for Assessing Learning in Programs

College and University mathematics faculty members have a long history of assessing student learning in individual courses. The major change brought on by the assessment movement of the past 20 years was the need to assess student learning in blocks of courses—more specifically, coherent blocks of courses—that are designed as part of a degree program. The block of courses required in a major is the most common block considered by various collegiate disciplines. Collegiate mathematics has that block and several more. In fact, many college and university mathematics departments have the following coherent blocks of courses designed as parts of various degree programs. The cases in this volume that address assessment in each block are indicated in parentheses.

- Developmental or remedial courses (NCC [Ch. 3] & Arizona [Ch. 11])
- Precalculus courses (NDSU [Ch. 2], VCU [Ch. 6], Alverno-Math [Ch. 5] & UTEP [Ch. 10])
- Courses for mathematics-intensive majors (NDSU [Ch. 2], USMA [Ch. 8], CSM [Ch. 9], UTEP [Ch. 10] & Arizona [Ch. 11])
- Courses for future teachers (NCC [Ch. 3] & KSC [Ch. 4])
- Courses for general education (VCU [Ch. 6] & Alverno-QL [Ch. 7])
- Courses for business students (Arizona [Ch. 11])
- Courses for undergraduate mathematics majors (KSC [Ch. 4] & Alverno-Math [Ch. 5])
- Courses for graduate degree programs (none)
- Innovations or reform courses (Alverno-Math [Ch. 5], VCU [Ch. 6], USMA [Ch. 8], UTEP [Ch. 10] & Arizona [Ch. 11])

All but the last innovations/reforms are usually blocks of two or more courses. Some institutions will have no developmental courses, while others will have as many as five. Precalculus courses include college algebra, trigonometry, analytic geometry, and elementary functions. Mathematics-intensive majors usually require at least two or three calculus courses plus differential equations. Recommendations for mathematics courses for future teachers by the Conference Board for the Mathematical Sciences (CBMS) (2001) include nine semester hours for future elementary teachers, 21 semester hours for future middle school teachers, and a mathematics major (usually more than 30 hours) plus a six-hour capstone course for future high school teachers. Business degree programs usually include at least two mathematics courses, often one in calculus and one in finite mathematics tailored after the course defined nationally by the book by Kemeny, Snell, and Thompson (1956).

Aside from innovations or reform courses, which are irregular by their very nature, the most variable offering among this group of nine blocks is the one for general education or quantitative literacy. Until recent years, the only prominent college mathematics course designed for general education was a course for liberal arts students that came into U.S. mathematics about 50 years ago (Allendorfer, 1947). Several circumstances have moved departments to consider new courses designed for general education. Among these circumstances are two that are dominant: the changing collegiate population with larger and larger percentage of high school students entering higher education (see Figure 3) and the quantification of U.S. society promoted in large part by computers (Madison, 2004; Madison and Steen, 2003; Steen, 2004). Until recently, the precalculus courses, especially college algebra, doubled as general education courses, and that is still the case at many institutions. However, more and more courses are being designed specifically for general education.

Conclusion

Collegiate mathematics in the U.S. has undergone major changes during the past half century. Faced with different student populations and a vastly different society, college mathematics needed to change its courses and programs. Assessment for evidence of learning to both direct and evaluate change is a powerful and essential tool. This, combined with external mandates, has pushed and is pushing assessment forward. This volume gives a variety of motivations, institutional circumstances, methods, and responses in the ten case studies and one lighthearted essay, which follow and describe rather well the landscape of assessment of student learning in collegiate mathematics.

References

Allendorfer, C. B. (1947). Mathematics for liberal arts students. *American Mathematical Monthly,* 17, 573–578.

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

American Mathematical Association of Two-Year Colleges (AMATYC). (2005). *Beyond crossroads draft version 6.0*. Memphis, TN: American Mathematical Association of Two-Year Colleges. Retrieved June 30, 2005, from http://www.amatyc.org/

Barr, R. B., & Tagg, J. (1995). From teaching to learning – a new paradigm for undergraduate education. *Change, 27*(6), 13–25.

Committee on the Mathematical Sciences in the Year 2000 (MS2000), National Research Council. (1991). *Moving beyond myths: Revitalizing undergraduate mathematics*. Washington, D.C., National Academies Press.

Committee on the Undergraduate Program in Mathematics (CUPM). (1991). The undergraduate major in the mathematical sciences. In Steen, L. A. (Ed.), *Heeding the call for change* (pp. 225–247). Washington, DC: Mathematical Association of America.

Committee on the Undergraduate Program in Mathematics (CUPM). (1995). Assessment of student learning for improving the undergraduate major in mathematics. *FOCUS: The Newsletter of the Mathematical Association of America*, *15* (3), 24–28. Reprinted in B. Gold, S. Z. Keith, & W. Marion (Eds.), *Assessment practices in undergraduate mathematics* (pp. 279-284). Washington, DC: Mathematical Association of America.

Committee on the Undergraduate Program in Mathematics (CUPM). (2004). *Undergraduate programs and courses in the mathematical sciences: CUPM curriculum guide 2004*. Washington, DC: Mathematical Association of America.

Conference Board of the Mathematical Sciences (CBMS). (2001). *Mathematical education of teachers*. Providence, RI and Washington, DC: American Mathematical Society and Mathematical Association of America.

Ewell, P. T. (2002). An emerging scholarship: A brief history of assessment. In T. W. Banta & Associates (Eds.), *Building a scholarship of assessment* (pp. 3–25). San Francisco, CA: Jossey-Bass.

Gold, B., Keith, S. Z., & Marion, W. (Eds.). (1999). *Assessment practices in undergraduate mathematics*. Washington, DC: Mathematical Association of America.

Kemeny, J. G., Snell, J. L., & Thompson, G. L. (1956). *Introduction to finite mathematics*. Englewood Cliffs, NJ: Prentice-Hall.

Lutzer, D. J., Maxwell, J. W., & Rodi, S. B. (2002*). Statistical abstract of undergraduate programs in the mathematical sciences in the United States: Fall 2000 CBMS Survey.* Providence, RI: American Mathematical Society.

Madison, B. L. (1992). Assessment of undergraduate mathematics. In L. A. Steen (Ed.), *Heeding the call for change: Suggestions for curricular action* (pp. 137–149). Washington, DC: Mathematical Association of America.

Madison, B. L. (1999). Assessment and the MAA. Foreword to B. Gold, S. Z. Keith, & W. A. Marion (Eds.), *Assessment practices in undergraduate mathematics* (pp. 7–8). Washington, DC: Mathematical Association of America.

Madison, B. L. (2003). Articulation and quantitative literacy: A view from inside mathematics. In B. L. Madison & L. A. Steen (Eds.), (2003), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp 153-164). Princeton, NJ: National Council on Education and the Disciplines.

Madison, B. L. (Summer 2004). Two mathematics: Ever the twain shall meet? *Peer Review, 6*(4), 9–12.

Madison, B. L. (2006). Tensions and tethers: Assessing learning in undergraduate mathematics. In L. A. Steen (Ed.), *Supporting assessment in undergraduate mathematics* (pp. 3–10). Washington, DC; Mathematical Association of America.

Madison, B. L., & Ganter, S. L. (2006). Mathematics and QUE: Oil and water? In R. J. Henry (Ed.), *Faculty development for student achievement* (pp. 145-172). Bolton, MA: Anker Publishing Company.

Madison, B. L., & Hart, T. A. (1990). *A Challenge of numbers: People in the mathematical sciences*. Washington, DC: National Academies Press.

Madison, B. L., & Steen, L. A. (Eds.). (2003). *Quantitative literacy: Why numeracy matters for schools and colleges*. Princeton, NJ: National Council on Education and the Disciplines.

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

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Snyder, T. D. (Ed.). (1993, January). *120 years of American education.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

Steen, L. A. (Ed.). (1987). *Calculus for a new century*. Washington, DC: Mathematical Association of America.

Steen, L. A. (Ed.). (1992). *Heeding the call for change*. Washington, DC: Mathematical Association of America.

Steen, L. A. (2004). *Achieving quantitative literacy.* Washington, DC: Mathematical Association of America.

Steen, L. A. (Ed.). (2006). *Supporting assessment in undergraduate mathematics*. Washington, DC: Mathematical Association of America.

CHAPTER 2
ASSESSING INTRODUCTORY MATHEMATICS: PARTNERING WITH FACULTY FROM OTHER DISCIPLINES

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Introduction

Two questions interest many faculty members in mathematics and other disciplines that use mathematics:

1. What mathematical knowledge and skills should students possess?
2. Do students possess that knowledge and those capabilities?

The first question is given considerable attention in mathematics departments, and the focus is often on the mathematics content of introductory courses. Departments design courses and introductory programs to include coverage of material that they believe is necessary for their students. These decisions are based on local discussions that often are influenced by recommendations from external bodies, such as the Mathematical Association of America Committee on the Undergraduate Program in Mathematics (MAA CUPM) recommendations for undergraduate programs in mathematics (2004), and review of the content of potential textbooks. Sometimes these discussions include input from client disciplines on the campus.

The second question generally takes two forms: (a) How well prepared are incoming students for our mathematics courses; and (b) How well have students performed in specific mathematics courses here? The first form is not uncommon in department meetings and informal conversations about the mathematical readiness of incoming undergraduate and graduate students. All faculty take responsibility for the second form of the question as they assign grades for students in their courses.

For more than a decade, accrediting associations in higher education have worked to increase the focus on assessment of student learning from a broader perspective than simply testing and grading in specific courses. Mathematics departments are recognizing the need to identify learning objectives of their programs and to assess the extent to which their students achieve these goals. Accrediting agencies have specified neither the objectives nor the assessment techniques, only that departments are responsible for devising appropriate goals and assessments.

The purpose of assessment is to determine whether instructional goals, or expectations for student learning, are being met. We have found that explicit goals statements, such as in course descriptions, focus on subject content rather than on the capabilities that students will develop. Such statements either are closely tied to individual courses or are too broad and content-focused to guide assessment of student learning. Complicating the situation, students study mathematics for myriad reasons; other departments require mathematics for varied purposes; and faculty members do not always share the same goals for undergraduate programs (Boyer, 1990), in particular, for mathematics.

This paper will discuss how mathematics departments can address the two questions and will give specific examples of how the original questions have been addressed in two mathematics departments over more than a decade. The purpose is not so much to promote a specific system, but rather to identify key issues and suggest strategies to address the issues. The focus is on assessment of student learning in *service courses*; that is, introductory mathematics courses usually taken by first- and second-year college students in which prospective mathematics majors are typically a minority of the enrollment.

Procedure

External sources, including professional organizations and textbook publishers, provide one source of information about the mathematics our students need. Publishers usually work with university faculty members as authors, developers, consultants, and reviewers of mathematics textbooks. Because mathematics departments and course instructors make textbook adoption decisions, the collegiate mathematics community has significant input into the nature of curricular materials that are available for its use. This market process largely accounts for the texts that find wide use in introductory mathematics courses—the publishers are not so much imposing a vision of mathematics in colleges as they are responding to marketing data primarily derived from the collegiate mathematics professoriate.

Professional organizations also prepare recommendations for the nature of undergraduate mathematics programs. The focus here tends to be on undergraduate majors in mathematical sciences and mathematics education (CUPM, 2004; Conference Board of the Mathematical Sciences [CBMS], 2001; MAA, 1993). An area that has come under increased scrutiny in recent years, however, is the focus of this paper and volume: the teaching and learning of introductory undergraduate mathematics, that is, the service courses through the level of university calculus, linear algebra, and differential equations. The two questions remain the same about this area: (a) What should students learn, and (b) What do students learn? In this paper we will describe some methods that have been used over an extended period to gain local insights into these two issues in relation to introductory collegiate mathematics.

The impetus for this work originally came externally to the mathematics department. As accrediting agencies and state government called for increased accountability for student learning in colleges and universities, some mathematicians sought to respond with assessment procedures that met the external requirements in a way that was useful both internally and externally. Their goal was to develop locally a procedure that seemed worthwhile to all participants, rather than simply administering tests and reporting scores to satisfy external constituencies. The goal was to have both internal utility and external credibility. The mathematicians and departments to which we refer in this narrative are at the University of Wisconsin–Madison (UW-Madison) and North Dakota State University (NDSU).

The first goal was to learn what students would need to know following their introductory mathematics studies. Some work has been done in this area by groups of mathematicians and individuals from client disciplines who have met and discussed the issues and prepared recommendations, for example, the recommendations of the Curriculum Renewal Across the First Two Years (CRAFTY) (2005) subcommittee of the CUPM. Our approach was different. We went to faculty in client disciplines and asked them to identify the skills and capabilities that their own students would actually use in their study—the mathematical knowledge that would be used in a specific course. The reason was to avoid generating a broad “wish list” of desirable knowledge and to instead focus on actual capabilities that would be used by the students in the course: Prerequisite knowledge that (a) the instructors expected their students to know from the start, (b) would not be taught in the course, and (c) was crucial for success in the course. Once identified, this mathematical content became the focus of the second project goal: a testing program that sought to document how student capabilities matched instructor expectations.

An immediate problem—and one faced by commercial testing companies as well—is the wide range of mathematics that is used by different client disciplines. The question of what a mathematics or mathematics education major needs to know has a relatively tight focus (though even it is subject to considerable debate). The question of what mathematics *any* college major might require is almost impossibly broad, since it encompasses such a disparate group of disciplines from journalism to statistics, from arts and social sciences to engineering, and from child development and elementary education to medicine and law.

Our response to this difficulty was to tailor our work to specific, representative disciplines from across the campus. Rather than devise a few general assessments that had broad application, we chose to tailor many specific assessments to particular courses and faculty. The process has been described previously (Bauman & Martin, 1995; Martin, 1996; Martin & Cömez, 2006). Briefly, we outline the process below.

The assessment procedure has four elements or phases:

1. Identification and selection of a representative sample of junior-level courses from across the campus.
2. Development of tests tied to expectations of instructors of specific courses.
3. Administration, scoring, and reporting of test results to participants within the first month of classes.
4. Follow-up surveys and reporting of broader summaries of findings to interested parties, including participating client, mathematics and statistics departments, and other external stakeholders.

Selecting Courses

Using the college catalog and schedule of courses, we select a variety of junior-level courses in terms of colleges, departments and the expected level of quantitative skills. We have identified three general levels of quantitative backgrounds, one of which is expected in most junior-level courses:

Level 1—precalculus-level high-school algebra and statistics;
Level 2—a single course of business or regular calculus; and
Level 3—the regular three-semester calculus sequence, possibly including differential equations.

We contact department chairs and course instructors to discuss possible participation in the project. No pressure is used for those uninterested or unwilling to participate, because the process depends on the "buy-in" of all participants, including the students who are to be assessed. We meet to explain the purpose and nature of the project, emphasizing our desire that all participants learn from the exercise. We believe it crucial that faculty not participate simply as a favor or under any sense of external pressure.

Test Preparation

Once a course is identified, the assessment process begins with a questionnaire and interviews with the course instructor. The questionnaire lists many topics that are covered in introductory mathematics and statistics courses. Our goal is for the instructor to identify the quantitative material that students need for success in the course. At the same time, we review course information such as syllabi, assignments, tests, and textbooks to identify quantitative material that is part of the course. Working with the instructor, and drawing from a collection of free-response assessment items developed and used previously, we collaboratively design a test to be administered to students in the course during the second or third week of classes.

Each test typically contains from 6–12 constructed-response items. In situations where the course instructors have more problem types than can be reasonably included on a single class-period test, we randomly split the class and use two parallel test versions to increase the number of problems available in a limited time frame. Since the focus is on student readiness for the course, not the learning that will be assessed by their instructor during the semester, it does not matter that students take different tests.

It is also crucial that we gain the cooperation and buy-in of the students who take the assessments. We learned that we could achieve this goal by having the course instructors tell their students that the test (a) would *not* count in their grade, (b) was designed by the instructor to reflect the quantitative skills they would need in the course that semester, and (c) would provide useful information both to them and to the instructor about the class's quantitative capabilities so that revision and adjustments could be made as needed during the course. While we mentioned that the process had a wider import than just this class, our focus in every case is on ensuring that the process has clear value to participants. In this way, we do not need to depend on altruistic motivation.

Test Scoring and Reporting

Our interest is on the degree of success students achieve on particular tasks, rather than on a summative test score. Sample assessments are available online (Martin & Cömez, 2003). We have developed a reliable method for undergraduate and graduate mathematics and statistics students to score these tests, which enables both a quick turnaround to students and retention of detailed data about student performance for our analysis.

Scorers record information about the steps students took when solving the problems. They also code the degree of success achieved on each problem using the following holistic rubric:

A. *Completely correct*
B. *Essentially correct*—student shows full understanding of solution and only makes a minor mistake
C. *Flawed response*, but quite close to a correct solution
D. *Took some appropriate action*, but far short of a solution
E. *Blank*, or nothing relevant to the problem

The graders record the information on opscan or scantron sheets and also write feedback on the test papers, which are returned to students within a week. Students receive suggested solutions to the problems on all test versions and cross references to sections of their current textbooks that cover the material so that they can review important mathematics for the course if they choose.

Summaries of the graders' coding are reported on a copy of the test so that the instructor can see both specific steps taken by students in the class and the distribution of overall success rates on each problem. For example, Figure 1 contains two items with their ratings. The italicized statements were used by the graders to indicate solution steps taken by students in the class. The percents refer to the proportion of students who took those actions in solving the problems and the proportions that received each of the overall ratings on the problem.

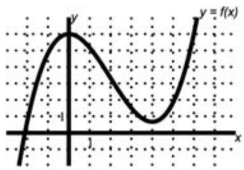
Figure 1
Sample Assessment Items with Scoring Summary

4. Suppose y is a differentiable function of x satisfying $x^2 + xy^2 + 3y = 11$ for every x in its domain. What is the <u>numerical</u> value of $\frac{dy}{dx}$ at the point (1,2)?

Used implicit differentiation (even if not completely correctly): 67%
Correctly used product rule for second term: 42%
Solved for $\frac{dy}{dx}$ correctly: 25%
Substituted x=1, y=2 to find numerical value 42%

Degree of Success: A 25% B 21% C 17% D 8% E 29%

5. Here is the graph of a function $y = f(x)$. Use the graph to answer these questions:



(a) Estimate $f'(4)$

Sketched tangent line at each point (not necessary) 88%
Commented on local minimum and/or horizontal tangent at x=4: 83%
Stated m=0: 25%

(b) Estimate $f'(2)$

Observed that gradient at x=2 is negative: 79%
Estimated at x=2, -3 < m < -1: 25%

(c) On which interval(s), if any, does it appear that $f'(x) < 0$?

Gave correct estimate for interval: 13%

Degree of Success: A 8% B 25% C 50% D 4% E 13%

These ratings are used to generate a test score—computed by awarding one point for each A or B code and zero points for each C, D, or E code—to reflect the number of problems that each student had essentially or completely correct. A second score can also be computed to reflect the distribution of partial credit scores, in which each problem was awarded 0–4 points according to the rubric rating, from E=0 to A=4. Instructors are more familiar with this score, since it more closely matches the way many grade their own tests. While ratings for each problem, as shown in Figure 1, provide information about specific strengths and weaknesses of the students in the course, the overall test scores provide a more general impression of the readiness of the students for the quantitative requirements of the course.

The sample reports available online (Martin & Cömez, 2003) indicate in more detail the rich information that this process provides about student backgrounds along with their capabilities in relation to instructor expectations. Instructors see most of this information during the first month of the course, which provides some very specific insights into how the quantitative capabilities of the current group of students match the instructor's expectations.

Assessment Findings[1]

Part of our interest is on the specific comparison in a given course on the match between instructor expectations and student performance. Our primary interest, however, is on a broader picture of how the mathematical, statistical and quantitative preparation of students by the time they are starting upper-division course work has enabled them to fully participate in those studies. This focus is no longer on specific courses—either in mathematics, statistics, or client disciplines—but on the more general quantitative readiness or literacy of college juniors for whatever expectations they encounter. This information requires more time and analysis to develop, although it is principally based on the specific tests that we have described.

First, we try to ensure that the test in each course has worked as intended. We survey course instructors, participating students, and graders to identify any process weaknesses that have come to light during the assessment. Instructors are asked whether the results contained any surprises, and whether or not the tests reflected their expectations and the requirements of the course. Often we will repeat the process in a course so that the instructor can modify the assessment to better reflect his or her expectations.

At the end of the semester students complete a questionnaire that asks if they believe the test covered material actually used in the course and whether success on the assessment, in their view, would accurately reflect quantitative skills necessary for success in the course. Graders are asked to comment on any problems they encountered while scoring the tests. All of this input is used to evaluate and modify the assessment process itself. Each year, we prepare a summary report of results from all the courses that are assessed. This information is given to both the mathematics department and the university assessment committee for review. Over time, a broader picture emerges about student capabilities midway through the undergraduate program.

Findings

One advantage of this assessment procedure is that individual faculty members do not feel directly threatened by assessment results. The test's content is prerequisite material for the course in which the test is given; instruction on this content is not provided in the assessed classes. Furthermore, the tests do not focus on specific mathematics or statistics courses; they examine the breadth of student knowledge developed over years of schooling. Specific problems may be tied directly to a particular course, but students would have taken those courses at different times from different people, and we do not attempt to track instructors or instruction dates. While results do not focus on individual instructors, we have found quite specific implications both for mathematics and statistics departments and for the programs of study in the client disciplines themselves. These implications arise from both results of individual assessments in particular courses and broader patterns that emerge over time.

Nature of Tests

Each test is designed for a specific course. All tests use constructed response rather than objective (matching or multiple-choice) questions. While hundreds of items have been written for use on the tests, some patterns in the types of problems emerged over time. The broadest generalization is that there are three levels of test content, corresponding to the types of courses described previously as: Level 1 (precalculus and statistics), Level 2 (first semester differential or business/social and life sciences calculus), and Level 3 (the regular three semester calculus sequence, possibly including differential equations and linear algebra). During this work, we found that the tests—recall that they reflect the expectations of the client faculty rather than those of the mathematics or statistics department—tended to have a focus on using mathematics to represent a situation, on interpreting data and graphical representations, or on interpreting the meaning of a mathematical representation for some problem situation. Less common were questions that simply focused on specific mathematical skills, such as integration by parts or factoring polynomial expressions.

We analyzed the types of questions that appeared on tests in a variety of courses over a five-year period. We found differing emphases on tests in upper-division mathematics, physical science, and engineering courses. These patterns for Level 3 courses were summarized in a table that is available online (Martin & Cömez, 2003, 2006, Appendix C). The table not only reports the proportion of problems drawn from various content areas, but also summarizes student performance on those items during the period of study.

We also analyzed the content of Level 1 and Level 2 tests and found a heavy emphasis on descriptive statistics, interpretation of data represented in graphical and tabular form, and related calculations with percentages. Table 1a and Table 1b provide a summary of the types of problems and student success rates observed in a variety of Level 1 courses over a number of years. Courses with Level 1 prerequisites (that is, precalculus and basic statistics only) were found in the natural sciences, social sciences, and professional programs. Table 1a displays the broad pattern of content areas and distribution of problem types that appeared on such assessments (both the actual number of problems that appeared on tests and the proportion of problem types).

Table 1a
Summary of Problem Types by Course Group (Level 1)

Problem Groups	Natural Science		Professional		Social Science		Row Summary	
Numeric/algebraic computation	40*	38%**	26	45%	116	43%	182	42%
Geometry	7	7%	0	0%	1	0%	8	2%
Graphs	30	29%	14	24%	71	26%	115	26%
Tabular Data-T	8	8%	18	31%	40	15%	66	15%
Probability and Statistics	19	18%	0	0%	44	16%	63	15%
Column Total	104	100%	58	100%	272	100%	434	100%

*Number of problems of this type that appeared on tests. **Percents are of all problems listed in that column.

Table 1b provides more detailed information about the problem topic areas and relative success rates that students had with different problem types. This summary information obtained from tests administered in a variety of departments and courses over many years paints a picture of the quantitative capabilities and expectations in undergraduate courses at the universities.

One outcome of this sort of meta-analysis of test results was a significant new quantitative requirement for undergraduate programs. The recognition that much of the content of these tests was not closely related to existing precalculus and statistics courses at UW–Madison led to implementation of a new quantitative literacy degree requirement (Bauman & Martin, 1995). Special new courses were developed to help develop the

Table 1b
Summary of Problem Types by Course Group (Level 1)

Problem Groups	Natural Science		Professional		Social Science		Row Totals	
Simplify and Evaluate	12-7*	12%(A)**	6-2	10%(AB)	67-7	25%(B)	85-16	20%(A)
Solve equations	3-3	3%(B)			3-2	1%(B)	6-5	1%(B)
Numeric computation	10-8	10%(B)	16-3	28%(B)	37-7	14%(A)	63-18	15%(B)
Represent/solve word probs.	15-7	14%(B)	4-2	7%(B)	9-2	3%(A)	28-11	6%(A)
Numeric/algebraic computation	40	38%	26	45%	116	43%	182	42%
Area and volume	4-3	4%(CD)					4-3	1%(CD)
Solve triangles	3-2	3%(A)			1-1	0%(A)	4-3	1%(A)
Geometry	7	7%	0	0%	1	0%	8	2%
Produce function graph	1-1	1%(C)			4-2	1%(BC)	5-3	1%(C)
Interpret function graph	23-8	22%(B)	2-1	3%(AB)	39-7	14%(C)	64-16	15%(B)
Interpret statistical graph	1-1	1%(B)	6-2	10%(CD)	13-5	5%(C)	20-8	5%(C)
Interpret scatterplot	5-4	5%(A)	6-3	10%(B)	15-5	6%(C)	26-12	6%(BC)
Graphs	30	29%	14	24%	71	26%	115	26%
Tabular Data–T	8	8%	18	31%	40	15%	66	15%
Calculate mean, median	4-3	4%(A)			23-7	8%(B)	27-10	6%(B)
Probability distributions	4-3	4%(B)			12-4	4%(BC)	16-7	4%(B)
Calculate summation	2-2	2%(BC)			7-2	3%(D)	9-4	2%(C)
Write summation formula					1-1	0%(D)	1-1	0%(D)
Probability–counting	3-3	3%(C)					3-3	1%(C)
Conditional probability	6-3	6%(D)			1-1	0%(D)	7-4	2%(D)
Probability and Statistics	19	18%	0	0%	44	16%	63	15%
Column Totals	104	100%	58	100%	272	100%	434	100%

*The number before the hyphen is the number of problems of that type that appeared on a test. The number after the hyphen is number of distinct courses that used at least one such problem.

**Percents are of all problems listed in that column. Because success rates vary somewhat, the median quartile of student success rates is reported in parentheses rather than the median success rate. The quartiles range from A: 76-100% to D: 0-25% of students were successful. Medians that fall between groups are written AB, BC, CD.

sort of quantitative capabilities that had appeared on our assessments in courses that had no formal mathematics or statistics prerequisites.

Student Performance

Faculty working with assessment often express concern that students will not take the assessment seriously, adversely affecting results. This has not been our experience in most courses. Mostly students express positive feelings on our end-of-semester survey about the validity of our tests in relation to their courses, particularly in Level 2 and Level 3 courses. Many students report reviewing the designated course prerequisite material for an hour or more both before and after the test, and most of them report seeing connections between the problems and the course work during the semester. The most common exception, though not universal, has been in Level 1 courses. Here we find some students who resent the assessment, even writing that they took this course or program because they did not want to study mathematics or statistics again.

As one probably should expect, given the time that has elapsed between formal study of mathematics and statistics and our assessment test administered in a later course, success rates and performance on the assessment tests often appear low. In analyzing success rates on assessment project tests, based on success rates (that is, proportion of students taking the test whose responses were rated A or B), the problems fall into one of three groups: High success with more than 70% of students getting a rating of A or B, medium success with around half of the class successful, and low success with under a third of the students successfully completing the problem. It is unusual to find many or the majority of problems with high success rates. Similarly, when we look at the test score for the number of problems each student had essentially correct, the distribution commonly has a median of about half of the problems. While this pattern might be expected, given the time lag mentioned previously, it also raises concerns. A review of the tests shows that the problems mostly would be considered at the basic level of difficulty in the mathematics or statistics course in which they were covered. The items were chosen by the course instructor to represent *prerequisite knowledge that is essential for success in the course and will not be covered in the course*. Both observations have led to concerns in the client disciplines and in the mathematics departments.

We have noted some broad patterns of student results across the three levels of courses. At each level, certain types of problems typically have high success rates, while other types of problems often have low success rates.

Table 2, which appeared in (Martin & Cömez, 2003, 2006), summarizes the broad pattern of results. The significance of this table is that there are apparent broad patterns that say something about the use of mathematical ideas outside of mathematics.

We have found that instructors often want students to be able to reason independently, to make interpretations and to draw on basic quantitative concepts in their courses; they seem less concerned about student recall of specific techniques. Students, on the other hand, are more successful with routine, standard computational tasks and often show less ability to use conceptual knowledge or insight to solve less standard problems (Bauman & Martin, 1995). For example, we expect to have high success rates on problems that ask students to use integration by parts or the chain rule for differentiation; we often have low success rates when we ask them to find the force on the face of a dam or sketch a graph of a function based on sign information about its first and second derivative.

Table 2
Patterns of Student Results

	Level 1 (No mathematics or statistics prerequisites)	Level 2 (Require 1 semester of calculus)	Level 3 (Expect 3 semesters of calculus)
High success	Basic arithmetic, statistics and conversions (computational) **Example**: temperature conversion	No common items for all subjects fit here (Basic statistics is an example) **Example**: change in mean	Most precalculus, use calculus formulas and techniques (e.g., differentiate) **Example**: evaluate integral
Mixed success	No common types across most courses at this level **Example**: compare proportions	Precalculus material, such as solving 2x2 systems or reading values off a graph **Example**: profit function	Concepts from calculus **Example**: estimate a derivative or integral from graph
Low success	Extract information from tables and graphs **Example**: 2x2 cross tabulation table	Nearly all calculus material **Example**: estimate derivative at point	Complex numbers, ODE's, series, and more complex "word problems" (such as optimization) **Example**: minimize can's surface area

Faculty Reactions

Faculty, particularly in our client disciplines, have reacted very positively to this project over the years. It requires a fair amount of time and effort to design tests and interpret results, and the work often stretches over at least a year by the time we assess, review, revise, reassess, and analyze again. Some faculty have continued to use the assessments as a useful pretest and review of mathematics for their students even after we finish the assessment project.

It is very common for faculty to view the performance of students as quite a bit lower than they would desire. Some faculty are resigned to this pattern of results, focusing on institutional or systemic factors beyond their control to account for the situation revealed by the assessment. Others question the results, suggesting that students may not have taken the assessment seriously since it did not count toward their grade, or that they just need some review to be able to perform better on skills rusty from disuse. Fortunately, still other faculty are disappointed by student performance and look for ways to respond to the results.

Some participating instructors report no need to make changes, since students had the prerequisite skills or the instructor, recognizing difficulties, had modified the course in response. Other instructors reported making adjustments, either by omitting reviews that no longer appeared necessary or by including additional work to develop missing capabilities.

Summary and Implications

Sampling from departments across the campus, information is gathered about (a) quantitative skills used in specific courses and (b) the extent to which students can show these important skills at the start of the semester. Instructors play a key role in helping to design free-response tests reflecting capabilities expected of students from the first week and essential for success in the course. Two important characteristics of this form of assessment are (a) direct faculty involvement and (b) close ties to student goals and backgrounds. We have found that the reflection, contacts, and dialogues promoted by this form of assessment are at least as important as the test results.

The important undergraduate service role of most mathematics departments is illustrated by some specific enrollment data for the UW-Madison Department of Mathematics: In fall 1994 the department had about 200 undergraduate majors and enrollments of about 6,500 in courses at the level of linear algebra, differential equations, and below. Some of these students go on to major in a mathematical science, but most are studying mathematics as technical preparation for work in other departments. Mathematics faculty members must perform a delicate balancing act as they design lower-division course work that must meet diverse expectations of client disciplines across the campus.

We report annually to the entire mathematics faculty, but we have probably had greater curricular influence by targeting our findings at individuals and committees responsible for specific levels or groups of courses, particularly precalculus and calculus. Findings from many assessed courses have shown, for instance, that faculty members want students to interpret graphical representations. This had not always been emphasized in our mathematics courses. It was ironic, but instructive, that in a meeting to discuss our findings with a mathematics curriculum group, one faculty member remarked about a problem that asked students to estimate a derivative from a graph of the function, “I’m not surprised students couldn’t do that—I never ask such questions in my class.” A colleague immediately responded that he thought such tasks were very important and always emphasized such ideas when he taught calculus.

Perhaps more important, though, is what our work shows about the kind of mathematical skills needed in other departments: That instructors seem less concerned about computational, algorithmic knowledge than more conceptual, problem-solving capabilities has implications not just for the *content* of mathematics courses, but also for the *way* we teach mathematics.

We produce a summary report for faculty members in participating departments and attend a faculty meeting to discuss issues raised by assessment. The information has stimulated a variety of departmental changes:

- After finding that many students in an introductory course were unable to handle material from calculus, one department increased the prerequisite from first semester business calculus to two semesters of the regular calculus sequence. They did this not because the students needed the additional content, but to ensure that their students had further developed the necessary fundamental ideas by using and reviewing them in their later mathematical work.

- In another department, many students had poor records for their college mathematics courses. In discussing assessment outcomes at a meeting, one faculty member remarked that students claimed they did not realize they would be expected to know material from a prerequisite calculus course in their later course work. This illustrated the importance of stressing ruing the advisement process, especially for first- and second-year students, the purpose of general education requirements.

- Faculty members in other departments typically welcome the interest of our committee, with its mathematics and statistics faculty members, in their quantitative expectations of students. Faculty in one non-technical department discussed the quantitative needs of their students as they restructured their undergraduate program and decided to incorporate more quantitative reasoning work in their lower-level courses.

- In another department, following a planning session with our group for an upcoming assessment, the coordinator for a large introductory science course (with a calculus prerequisite) remarked that he “couldn’t remember having spent even five minutes discussing the specific quantitative needs of students with colleagues” during his years at the university.

Faculty contacts are central to this form of assessment. The validity of our findings depends on instructors ensuring that the test we design accurately reflects their quantitative expectations. It is worth emphasizing that the main advantage of this approach is in the ongoing dialogue about student knowledge and learning that is promoted, indeed required, to conduct the assessment. Important advantages of this assessment method include that:

- Faculty members must focus on specific course expectations to prepare an appropriate test.

- Student needs and backgrounds are reflected in the assessment process because the test is tied to a course the student has chosen, usually at the start of their studies in the major.

- Faculty from mathematics, statistics, and client departments talk about faculty expectations, student needs, and student performance in relation to specific courses and programs.

- The conversations are tightly focused on the reality of existing course content and written evidence from students about their quantitative capabilities.

- Everyone involved, students and faculty, gains useful information that has immediate significance apart from its broader, long-term institutional meaning.

Endnote

1 The discussion of results and findings in this paper are based on assessment activities at both institutions: NDSU and UW-Madison over the period 1990–2004.

References

Bauman, S. F., & Martin, W. O. (1995). Assessing the quantitative skills of college juniors. *The College Mathematics Journal, 26*(3), 214-220.

Boyer, E. L. (1990). *Scholarship reconsidered: Priorities of the professoriate*. Princeton, NJ: Princeton University Press.

Committee on the Undergraduate Program in Mathematics (CUPM). (2004). *Undergraduate programs and courses in the mathematical sciences: CUPM curriculum guide 2004*. Washington, DC: Mathematical Association of America.

Conference Board of the Mathematical Sciences (CBMS). (2001). *Issues in mathematics education volume 11: The mathematical education of teachers*. Providence, RI and Washington, DC: American Mathematical Society and Mathematical Association of America.

Curriculum Renewal Across the First Two Years (CRAFTY). (2005). *Curriculum foundations project: Voices of the partner disciplines*. Washington, DC: Mathematical Association of America.

Martin, W. O. (1996). Assessment of students' quantitative needs and proficiencies. In T. W. Banta, J. P. Lund, K. E. Black, & F. W. Oblander (Eds.), *Assessment in practice: Putting principles to work on college campuses* (pp. 216-219). San Francisco, CA: Jossey-Bass.

Martin, W. O., & Cömez, D. (2003). Developing a departmental assessment program: North Dakota State University mathematics. Mathematical Association of America Project SAUM. Retrieved February 6, 2006, from http://www.maa.org/SAUM/new_cases/new_case_11_03/assessNDSUr3.html

Martin, W. O., & Cömez, D. (2006). Developing a departmental assessment program. In L. A. Steen (Ed.), *Supporting assessment in undergraduate mathematics* (pp. 93-101). Washington, DC: Mathematical Association of America.

Mathematical Association of America (MAA). (1993). *Guidelines for programs and departments in undergraduate mathematical sciences.* Washington, DC: Mathematical Association of America.

CHAPTER 3
SUCCESS WITH ASSESSMENT: RESPONDING TO A SYSTEM MANDATE

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Introduction

In 1987, the State University of New York (SUNY) mandated that all colleges and universities in the SUNY system begin a process of self-evaluation and assessment of student learning. This process is an ongoing college-wide endeavor with the ultimate goal of engaging in systematic efforts to maximize students' learning. The Mathematics/Statistics/Computer Processing (MSCP) Department of Nassau Community College (NCC), with seventy-seven full-time faculty members, has worked to design and implement course-level assessment for all its courses. The process has evolved dynamically as the mandates from SUNY have been modified. The current plan requires that all department courses be assessed within a six-year cycle. Assessment has been a catalyst for change, prompting faculty to modify existing courses, develop new courses, improve teaching techniques, and open a dialogue within the college community. A discussion of this evolution is described in this paper.

Background

Nassau Community College, the largest of the 30 SUNY colleges, is located thirty miles east of New York City on Long Island. Twenty-five percent of all college-bound high school graduates in Nassau County enroll in NCC, and in 2002 NCC had more than 21,000 students.

The development of the college's current assessment process began in response to the 1987 policy directive from SUNY Central to all SUNY campuses. The directive instructed each SUNY campus to formulate and submit a plan to assess student learning and development in four critical areas of the college curriculum: basic skills, general education, specialized (major), and personal and social development. The directive led to the creation of the Academic Senate Assessment Committee (ASAC), a college-wide committee responsible for developing and directing the implementation of course-level assessment in which faculty and departments would engage in the ongoing process of measuring and evaluating student learning outcomes. This committee comprised 49 faculty members from all college departments. The ASAC is charged with assisting all departments in this process of course-level assessment and communicating these results and findings to the college community in an effort to improve student learning. Each academic department is asked to form its own assessment committee, use ASAC guidelines and standards to assess the learning of its students, and report findings directly to the ASAC (ASAC, 1999).

The MSCP Department responded by creating the Department Assessment Committee (DAC) to monitor the assessment of all courses offered by the department as prescribed by the college and SUNY. As responsibilities increased, DAC membership was formalized, and seven departmental faculty members were elected to serve on this committee for two-year terms. Some DAC members were also members of the ASAC, so assessment requirements and ideas from the ASAC were brought back to DAC from ASAC and discussed with the entire DAC in order to develop plans that best fit the department. The DAC then sought input from the departmental course committees, which were responsible for monitoring the content of their respective courses and designing appropriate assessment tools. Further, the DAC consulted with other concerned faculty to gain ideas and insight to make the assessment successful. At the end of this process, the DAC charged the individual course committees with implementing the resulting assessment plans.

Description of the Assessment Process in Lower Level Courses

To serve the varying needs of the students at NCC, the MSCP Department offers 23 mathematics courses. Based on purpose, these courses are sorted as follows.

1. Three developmental courses
   a) College Preparatory Mathematics
   b) Introductory Algebra
   c) Integrated Arithmetic and Introductory Algebra

2. Twelve general education courses (GenEd)
   a) Topical Approach to Mathematics
   b) Concepts of Mathematics — Logic and Set Theory
   c) Introduction to Statistics
   d) Computers and Applied Statistics
   e) Algebra and Trigonometry
   f) Elementary Functions – Precalculus
   g) Calculus with Applications in Business and Social Sciences
   h) Engineering Technical Mathematics I
   i) Engineering Technical Mathematics II
   j) Finite Mathematics and Quantitative Analysis
   k) Calculus I
   l) Calculus II

3. Seven upper level courses
   a) Probability with Statistical Inference
   b) Foundations of Advanced Mathematics
   c) Multivariable Calculus
   d) Linear Algebra and Differential Equations
   e) Elementary Differential Equations
   f) Algebraic Structures
   g) Discrete Mathematics Structures

4. One course, Foundations of Mathematics for the Elementary School Teacher, serves students wishing to complete a four-year degree in elementary education.

The twelve GenEd courses, which include the four courses taken by a majority of the NCC liberal arts students (Topical Approach to Mathematics, Logic and Set Theory, Introduction to Statistics, and Algebra and Trigonometry), have been assessed using two different rubrics. Before 2002, the department used its own goal based assessment (GBA), shown in Figure 1, requiring course committees to decide goals and outcomes for their respective courses. This was then modified by a charge from SUNY that mandated the goals and the method of reporting outcomes (General Education Assessment Review Group, 2001). The design, implementation, and results of both of these methods are described below.

Figure 1
The Departmental Assessment Matrix Prior to 2002

COURSE: ________________________________

GOALS General Goal Statement plus at least 3 to 5 specific goals.	BEHAVIORS The actions performed and the information mastered which demonstrate progress toward the attainment of the course or department goals. (Must be measurable or observable.)	MEASURING INSTRUMENTS Instruments used to determine the extent to which the behaviors have been mastered. These may be written, oral, activity based, or a combination of these.	EVALUATIONS/ STANDARDS This area examines the results of the measurements and what they reveal. They must respond to the results generated by your measuring instruments.	MODIFICATIONS These must respond to the results of the measurements.
I. General Goal:				
II. Specific Goals: A.				
B.				
C.				
D.				

Goal Based Assessment Matrix

The GBA matrix is the instrument used in the documentation and reporting of information pertinent to the design, implementation, and evaluation of the classroom performance assessment process. The primary objective of this process is to elevate the quality of student learning experiences and outcomes in the mathematics courses offered by the department. The ASAC charged departments to assess student learning continuously. It was expected that for each course offered, one general learning goal and two course-specific goals would be assessed and then re-assessed using modifications faculty deemed appropriate based on findings of the first assessment (ASAC, 2001). All MSCP faculty (77 full-time and over 150 adjunct) were required to adhere to the guidelines established by the ASAC in implementing the evaluation of the learning outcomes.

The GBA matrix (see Figure 1) is divided into five columns that are used to summarize the aspects of the assessment process for each course.

The first column (*Goals* or, more specifically, *Teaching/Learning Goals*) addresses the question: What main concepts, skills, and/or principles do our students need to learn from this lesson, unit, or course? An example of a general goal is to have students able to use symbolic notation, which would include using variables from an algebra course, operators in a logic course, or parameters to describe data. In contrast, a course-specific goal relates to a particular aspect of a given course. An example of such a goal for a statistics course is for students to use statistical methods to represent and describe data sets. Individual instructors contribute to the collective effort to formulate the goals that are assessed for each course, thereby providing standardization of goals.

The second column of the matrix (*Behaviors* or *Outcome Behavior*) seeks to answer the question: What are students expected to do in order to demonstrate that the learning goal was achieved (that the expected learning occurred)? Faculty must identify appropriate behaviors that are deemed important outcomes of the learning process. For an elementary statistics course, typical outcome behaviors might require students to represent a set of data by a frequency distribution; calculate the mean, median, mode, and standard deviation of the distribution; or interpret these measures for samples and for populations.

The third column of the matrix (*Measuring Instruments* or *Measurements*) delineates the strategies *(i.e.*, instruments, tools, activities, devices, techniques) that should be used to demonstrate the extent to which learning goals were achieved. The departmental course committees designed these measurements, which consisted of a series of questions that could be used by all instructors teaching a specific course. These course-specific questions are fashioned for unobtrusive use by instructors in their courses. Questions could be embedded in examinations or quizzes, or given as a separate quiz. While quiz questions are the instruments used by most of the mathematics faculty as measurement tools, it is possible to use homework assignments or projects as alternative instruments, provided these assignments can fairly indicate whether or not a student is meeting the outcome objectives. Quiz questions provide the most effective and least intrusive way to implement an assessment of mathematics courses that have thirty or forty sections in a given semester, such as Logic and Set Theory or Introduction to Statistics.

The fourth column of the matrix (*Evaluations/Standards*) is used to analyze the measurement results, determine the student achievement and provide a yardstick that measures the extent of learning. The following questions are addressed in the evaluation column:

- To what extent did learning take place?
- How did the measurement instrument contribute to the achievement of the learning goal?
- What does student feedback tell us about how they learn?

The results of the measuring instruments are sent to the individual mathematics course committees to compile the results, often done quantitatively. Typically, committees identify the percent of students who took the quizzes and identify the percent of students who exhibited the appropriate outcomes. Although not as prevalent, some faculty prefer to use qualitative statements to report their evaluation. Examples of qualitative statements are:

"The first exam typically serves to alert the students that this is a serious math course!!! Grades generally range from F to B (and occasionally A). By the second exam, the majority of students appear to be on the right track." "On average, about one third of the class does a fine job for the first presentation. The remaining students generally need some advice regarding clarity and the use of presentation media (board, overheads, etc.)."

The final column of the GBA matrix (*Modifications* or *Recommendations*) is the bridge between the original assessment and the re-assessment of the same learning goals. Based on the results of classroom assessment, modifications may be made to improve the students' chances of achieving the learning goals. Implemented modifications then provide the basis for subsequent assessments, testing their effectiveness toward intended improvements. Examples of recommendations that have been suggested include:

- Formal instruction on calculator usage should be mandatory for all sections of elementary statistics.
- Better understanding of the practical interpretation of the maximum/minimum point of the parabolic function is needed.

- Greater emphasis needs to be employed on verbal translation of proportion problems.
- Faculty may consider a brief review of basic properties of exponents when time permits.

Once the recommendations have been adopted, a re-assessment of the original goals is performed to see if learning outcomes are more clearly exhibited. Thus, assessment of all mathematics courses offered at NCC is an evolving and continuing process. Under the new guidelines established by SUNY (beginning in the fall 2005 semester), the complete re-assessment for any course undergoing such a procedure must be scheduled within a six-year cycle.

The SUNY GenEd Assessment

In addition to the regular assessment of mathematics courses, in 2002, SUNY instituted the requirement that a GenEd Assessment be performed to assess the learning goals defined specifically by SUNY. In response, the DAC identified the courses that fell under the jurisdiction of the GenEd competencies and performed the SUNY GenEd assessment for each of these courses. Initially, these goals were defined by SUNY to help students develop competence in the knowledge and skills areas of mathematics, including: (1) Arithmetic; (2) Algebra; (3) Geometry; (4) Data Analysis and, (5) Quantitative Reasoning, as shown in Figure 2.

Goals in these five areas were stated in the first column of a matrix similar to the GBA matrix of 1987. SUNY further required that the department identify the extent (*none, some, moderate, strong*) to which these goals have been emphasized in each course. Additionally, the DAC used the SUNY guidelines to establish a set of outcome objectives (second matrix column) specifically for the GenEd assessment. These subject-appropriate outcomes are:

- Use the symbolic language and notations of mathematics.
- Use computational techniques in problem solving.
- Apply mathematical methods and models to the analysis of a variety of theoretical and life situations.
- Apply mathematical reasoning to interpret and evaluate mathematical information.
- Utilize technology in mathematics applications and in the collection, processing, and presentation of mathematical information.

The third column in the 2002 SUNY matrix required a description of the measurement strategy. The strategies listed by SUNY were the following.

- Paper/report

- Examination/short responses
- Examination /extended responses
- Oral presentations
- Assignment
- Laboratory/field project
- Other

Figure 2
The SUNY Assessment Matrix.

SUMMARY ASSESSMENT MATRIX
GENERAL EDUCATION – MATHEMATICS
COURSE NO. ___________ COURSE TITLE ______________________________ DATE _____

SUNY LEARNING GOAL **What faculty want students to learn from their teaching in a particular course.**	**OUTCOME OBJECTIVES** **Observable student behaviors / actions demonstrating that the desired learning has occurred.**	**MEASUREMENTS** **Measurement design for collecting data evidencing students' achievement of desired learning outcomes.**	**EVALUATION** **Interpretation/analysis of measurement results regarding the extent to which students are achieving expectations.**	**MODIFICATIONS & IMPROVEMENTS** **Actions taken to address assessment findings and expected improvements in learning outcomes.**
To help students develop competence in the knowledge and skills areas of mathematics, including: (1) Arithmetic (2) Algebra (3) Geometry (4) Data analysis (5) Quantitative Reasoning Extent of emphasis of each of the above areas: __________ None __________ Some __________ Moderate __________ Strong	Students will demonstrate competence in the knowledge & skills areas of mathematics by their ability to perform the following in subject-appropriate situations: • Use the symbolic language and notations of mathematics • Use computational techniques in problem-solving • Apply mathematical methods and models to the analysis of a variety of theoretical and life situations • Apply mathematical reasoning to interpret and evaluate mathematical information • Utilize technology in math applications and in the collection, processing and presentation of mathematical information	Measurement Strategy: ______ Paper/Report ______ Exam-Short Response ______ Exam-Extended Response ______ Oral Presentation ______ Assignment ______ Lab/Field Project ______ ______________ (Other-Specify) Description:	Participation: N % FT Faculty ___ PT Faculty ___ Students ___ ___ Sections ___ ___ Student Performance Toward Expectations: N % Not Meeting ___ ___ Approaching ___ ___ Meeting ___ ___ Exceeding ___ ___ Total ___ ___ Description of Criteria & Measurement Results:	Modifications: Improvements:

While the tools for the GenEd assessment were compiled and administered primarily in the same fashion as for the non-GenEd assessment, SUNY required that the numbers of students *exceeding, meeting, approaching*, and *not meeting* learning expectations be recorded. These results were tabulated based on the measurement data and presented in the *Evaluation* column. *Modifications and improvements* to learning (the final column) were then identified and considered for re-assessment.

Effective fall 2005, each mathematics GenEd course is to be assessed (with findings reported to SUNY by spring 2007) during a six-year cycle, using a more comprehensive and detailed set of learning goals established by a SUNY-appointed faculty panel. The new mathematics goals (standards) require students to demonstrate the ability to do the following.

- Interpret and draw inferences from mathematical models such as formulas, graphs, tables, and schematics.
- Represent mathematical information symbolically, visually, numerically, and verbally.
- Employ quantitative methods such as arithmetic, algebra, geometry, or statistics to solve problems.
- Estimate and check mathematical results for reasonableness.
- Recognize the limits of mathematical and statistical methods.

Accordingly, departmental course committees will design measures to assess the course-specific learning goals as prescribed by SUNY and the results will be evaluated. The levels of student performance are described as *exemplary, generally correct, partially correct*, and *incorrect*. A rubric for determining these levels has been designed for each of the five goals stated above.

Coordination between Lower Level Courses and Upper Levels Courses

The assessment procedures described above are also used to assess the upper level courses taken by the college's mathematics majors. The courses required of these majors are Calculus I and II, Discrete Mathematical Structures, Multivariable Calculus, Foundations of Advanced Mathematics, Linear Algebra and Differential Equations and Probability with Statistical Inference. The majors must also take two elective mathematics courses, which are not lower than Calculus I. Courses above Calculus II are reviewed using goals and objectives determined by the respective course committees. The format for these assessments was previously designated as Goals Assessment Format for Individual Departments and is now called Goals Based Assessment (GBA). Because there are fewer sections of upper level courses and many of them are single offerings, faculty teaching these courses often design their own measurement tools. The dominant tool is the faculty member's own examinations, and faculty report their results using both quantitative and qualitative methods.

In the assessments in these upper level courses, faculty have noted that their students have lost skills they possessed in algebra and precalculus and also need more practice in problem solving. This information has led to more coordination between the upper and lower level courses to determine what topics require more emphasis. The department anticipates that modifications in the lower courses will better prepare students for the sequential upper level courses.

Modifications Based on Assessment

When the results of the assessment in all three areas as discussed above were analyzed, it became evident that students at all levels were experiencing difficulties with the same issues. These included irregular attendance, inexperience using the calculator for more than arithmetic, lack of required algebraic skills, and the inability to solve problems. To address these issues and prepare students for upper level courses, modifications were needed.

The course committees for the three developmental courses made regular attendance a paramount requirement for courses. Course committees established a strict policy whereby students who exceeded the maximum number of absences (for example, six in the first developmental course) are prohibited from taking the final examination. Since successfully passing the final examination is a course requirement, excessive absences result in not passing the course. Some faculty in credit-bearing courses (i.e., non-developmental) have introduced contracts between students and themselves. These contracts explicitly state what is expected from the students. Contracts include attendance requirements, ramifications of not following the prescribed withdrawal procedure, type of calculator required, dates for tests/quizzes/projects, and the amount of time that the students are expected to spend outside the classroom preparing for class. The contracts also list faculty office hours and mathematics laboratory facilities as well as the grading policy used to determine the final grade. Students are asked to sign these contracts to verify that they understand both their role in the learning process and the demands of their instructor.

Graphing calculators have become a vital tool for the study of high school and early college mathematics. However, many students are intimidated when required to perform more than rudimentary calculations. From the modifications stated in the assessment matrix, faculty recommended that graphing calculators be introduced and used as early as possible so that students will be ready for the more complex usage required in upper level courses. Faculty require that calculators be brought to all classes so that students can learn how to use them gradually as new topics are introduced. Most faculty use the Texas Instrument ViewScreen™, a projection device for the instructor's calculator window, allowing students to follow the instructor in the problem solving process.

The assessment of student learning in the area of applied problems highlighted the need for greater emphasis on problem solving techniques. Students are also being made aware that reading a problem carefully to understand what is being asked is an essential first step in solving problems. Surprisingly, faculty teaching upper level courses voiced the concern for improved reading skills as did those teaching lower level courses. Thus, faculty now require students to explain what is being asked, describe how to solve the problem, find the solution, and then present the answer. Although students are provided with this algorithmic process, they still experience difficulty applying it to the problems they encounter. Consequently, faculty have increased the number and variety of word problems or contextual problems that students are asked to solve. These include problems that require students to interpret answers, to provide answers in complete sentences, and to include appropriate units and symbols. In order to make these problems more relevant and interesting to students, faculty are developing and using questions and problems that are based on real life situations and using personal data collected from students (anonymously as a group) as well as data from journals and research articles.

The department also recommended that students be taught using the *Rule of Four*, which is a paradigm developed by Deborah Hughes Hallett and the Calculus Consortium based at Harvard University (Hughes Hallett, 2003). This paradigm stresses that whenever possible, mathematical concepts are presented graphically, numerically, symbolically, and verbally, particularly in precalculus and calculus. This paradigm should be introduced as early as possible in courses prior to precalculus so that students will be prepared to use these techniques in the upper level courses. Furthermore, students are pushed to realize that often there are multiple techniques that can be used to solve a problem.

When assessment results were examined, it was determined that an impediment to student learning at all levels was students' failure to remember previously studied mathematics. As a result, more faculty are using diagnostic pre-testing. This has enabled faculty to determine the knowledge with which the students begin, to assess what has been learned in the previous course, to adjust the starting point of the class, and to anticipate where students are most likely to experience trouble. Although students are informed of the availability of extra help from their instructor as well as from the departmental mathematics center, this pre-testing alerts faculty to students who should avail themselves of these services.

Assessment as a Catalyst for Change in the Department

On a broader scale, the department has reacted to assessment findings in very tangible ways. Some of these are outlined below.

The assessment process heightened awareness of the necessity and benefits of discussing classroom methods that have resulted in successful learning. In order to foster such discussion, the department has instituted an end-of-year symposium where faculty share the results of assessment and discuss new teaching methods and novel ways to help students learn. These methods are quite varied and range from psychological techniques such as anxiety and stress reduction and breathing techniques to more concrete actions that include student projects and journals, new manuals, a re-evaluation of upper level courses, and development of new courses.

Anxiety Management

Anxiety and stress experienced by many students prevent them from being successful in mathematics courses. The department is fortunate to have a specially trained faculty member who offers students mathematics anxiety workshops. These workshops are often one-on-one sessions during which the mathematics anxiety specialist interviews students and suggests methods that can alleviate anxiety. During the recent symposium, another faculty member demonstrated the relaxing techniques she has taught her remedial students. She asks students to visualize themselves doing homework and taking a test. By helping the students visualize successful studying and test taking, she helps them gain confidence, encourages them to study more, and helps them to create a positive cycle of success. Another method to help students maintain a positive outlook required students to create a journal to track their progress in mathematics and to express their feelings about mathematics. This has helped students analyze why they have not succeeded in the past and what action they should take to change this outcome. Reading and writing assignments have also been incorporated in other courses. In Integrated Arithmetic and Introductory Algebra, for example, students were asked to recall experiences that may have contributed to feelings of frustration in mathematics courses. These may include a memory of a humiliating experience in school or an unpleasant interaction with a parent. These writing assignments are often done in conjunction with the book *Managing the Mean Math Blues* (Ooten, 2003), which features projects to help students realize that many of their feelings about mathematics are really “thought distortions” such as, “I better not ask questions because the teacher and students will know that I’m inadequate.”

Discovery and Relevance

Worksheets are being incorporated into many courses. Faculty use an approach that enables students to discover knowledge rather than be told a myriad of seemingly unassociated facts. Students should arrive at a deeper understanding of the concepts using this technique. This expectation will be measured in the next assessment.

On a more concrete level, project ideas have been shared for many courses. Since members of the department are in agreement that students are more interested in mathematics when they view it as relevant to their lives, many faculty are using student data for statistical analysis in Introduction to Statistics. Students are asked to complete an anonymous survey, and the results form the basis for several class projects in statistics. Students working in teams of no more than four must submit one completed project. The best submission earns extra points for the group, and the project is presented to the class by the team. The benefits of these projects are numerous: students use the statistical tools they learned to prepare a professional report, they improve team-working skills, they are rewarded in a competitive environment, and they improve presentation skills.

Assistance with Technology

Assessment has also provided the realization that students require assistance with technology, especially with graphing calculators, which now plays a larger role in teaching and learning of mathematics. This presents a problem for many returning students who graduated from high school prior to the introduction of graphing calculators. These students face a two-fold problem: learning the mathematics and learning how to use the calculator to obtain results. Members of the department have devised simplified instruction manuals to help students more easily use the calculator. This allows more class time to discuss the implication of the results of their calculations. The sequence of topics in a course may also be changed to allow students to become comfortable using the calculator for simple procedures before moving to problems that require complicated procedures.

Need for New Courses

The year-end symposium is also a forum for faculty to re-evaluate course content in upper level courses and to determine if new courses should be developed to reflect the changing needs of students. Consequently, course committees are investigating the algebra sequence offered by the department in order to ease the transition from remediation to college algebra and trigonometry and then onto precalculus.

Courses have been developed based on assessment results. The NCC mathematics placement examination (administered to entering students) may indicate that a student must pass both College Preparatory Mathematics and Introductory Algebra before he or she can begin college level mathematics courses. A new remedial course, Integrated Arithmetic and Introductory Algebra, was introduced in the fall 2003 semester, specifically designed for those students who are more motivated learners or who may be discouraged to learn that they need to take two remedial courses. It integrates the arithmetic and algebra into a six-contact hour course that meets four times a week for seventy-five minutes. Students who successfully complete the six-hour course can proceed directly into credit-bearing courses. The integrated approach with the intense class schedule has proven successful.

Our existing Introductory Algebra sections has been modified to help students who have already failed this course twice. At NCC, students who fail a remedial course three times are dropped from the college and must wait one year to apply for re-admission. A special section of Introductory Algebra is offered to these students who are on their third try at the course. This section meets one extra period each week and has fewer students. This will allow students more instructional time and more personalized attention. Another innovation is the introduction of the course Foundations of Mathematics for the Elementary School Teacher for students who want to complete a four-year degree in elementary education. This course uses group work and includes topics that will enhance the students' understanding of the fundamentals of mathematics. The use of manipulatives and hands-on activities are stressed.

Conclusions

The SUNY assessment process has been a learning experience for faculty and has provided them with many intriguing results. In addition to the expected results such as need for new courses, modification of existing courses to provide a seamless transition from one level to another, and promotion of student-centered environments, perhaps the most striking outcome was the recognition of the dual responsibility in the learning process (Cheifetz, 2005). The department has embraced the belief that both faculty and students must play active roles if the learning process is to be successful. The best-designed course or curriculum, taught by a master teacher, cannot succeed unless there is active participation by students. Thus, members of the MSCP Department believe that more emphasis should be placed on students' responsibilities in the educational process. While teachers set the standards, students must realize that more than mere class attendance is necessary to achieve success in most courses. The insistence that homework assignments be completed—and in a timely manner—cannot be overstated. Faculty assist reluctant students by demanding stricter standards for attendance and on-time submission of required projects and problem sets. These standards are now being stated clearly in course syllabi. Moreover, to help students develop good work habits, assignments and projects are being assigned in stages. This design helps students manage their time and complete assignments as required.

By monitoring assessment results, the department can refine the assessment process and continue to evaluate strengths and weaknesses. Shoring up weaknesses and taking advantage of strengths, student learning can be improved. The ongoing process will enable faculty, students, and the college to achieve the learning goals that are deemed appropriate for student success, both now and in the future.

References

Academic Senate Assessment Committee (ASAC). (1999, February). *Concepts & procedures for academic assessment*. Garden City, NY: Nassau Community College.

Academic Senate Assessment Committee (ASAC). (2001, February). *Quick start to classroom assessment*. Garden City, NY: Nassau Community College.

Cheifetz, P. (2005). *It seems to me.* Retrieved October 7, 2005, from http://www.matcmp.sunynassau.edu/~cheifp/Itseemstome1.htm

General Education Assessment Review Group. (2001). *Review process guidelines*. Albany, NY: State University of New York.

Hughes Hallett, D., et al. (2003). *Calculus.* Hoboken, NJ: John Wiley and Sons, Inc.

Ooten, C. (2003). *Managing the mean math blues.* Englewood Cliffs, NJ: Prentice Hall.

CHAPTER 4
A *CRAWL, WALK, RUN* APPROACH TO ASSESSMENT

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Introduction

This chapter captures the essence of the assessment activities in mathematics at a public liberal arts college, Keene State College, from the inception of our assessment program to its present state. Many of the lessons learned described here will be relevant to other institutions of varying size and mission. The fundamental issues we grappled with will be similar to issues other departments wrestle with in developing, restarting, or sustaining assessment programs.

Because different departments have different motivations for assessing programs, I will first describe what motivated us to assess our program. Doing so puts our program in context to facilitate understanding of our activities. Because ours is a relatively small and cohesive department with seven tenure-track faculty, our intention from the outset was to develop an assessment program that would be inclusive of all faculty in the department. Because obtaining faculty *buy-in* is important in assessment in undergraduate programs, a considerable part of this chapter will be a discussion of strategies to promote faculty involvement in program assessment. We purposefully decided that we would approach program assessment gradually—a *crawl, walk, run* approach to assessment—and learned there are many good reasons for doing just that. Although this chapter describes the specific assessment activities we undertook and the resulting impact of the assessment on our curriculum and pedagogy, I include the specifics only to promote understanding of the evolution of the more important general process. The chapter concludes with a description of results, recommended and implemented program changes, and the successes and failures in implementing changes.

Institutional Support of Departments for Program Assessment

The principal reason for program assessment is to improve student learning. That reason sounds great, and is in fact the best reason for doing program assessment, but other motivations affect faculty commitment to engage in program assessment. This section addresses some of the external motivations, but most of the discussion is focused on developing an internal motivation for assessment. When faculty internalize that program assessment can improve student learning, assessment activities have a greater probability of effectiveness and sustainability.

At Keene State College, the initial motivation was external, as the periodic regional accreditation team found our college-wide assessment effort lacking. As a result, college administration directed academic departments to begin program assessment with the disciplinary majors and required annual assessment reports from departments. The college supported initial departmental efforts in three major ways. First, administration constituted an Assessment Advisory Committee to oversee the college-wide assessment effort. Second, a team of “expert” consultants from another university was hired to advise our faculty and staff. Additionally, the administration funded faculty attendance at appropriate assessment related conferences.

Included in the latter was support for faculty attendance at both discipline-specific and more general assessment conferences. I found attending an American Association of Higher Education (AAHE) assessment conference enlightening, as it became clear that there was much to learn from others who have survived the growing pains of nascent assessment programs. Our own embryonic program could benefit much from the efforts of others—I came to realize we would not have to reinvent the wheel only to create a flat tire. Others have much to share to help us improve our chances of success. Many colleges and universities had burgeoning assessment programs in various stages of maturity, and it would be beneficial to learn about the efforts of others, then borrow and adapt those efforts as appropriate for our purposes.

If the AAHE assessment conference was an illuminating floodlight, the discipline-specific Mathematical Association of America (MAA) project Supporting Assessment of Undergraduate Mathematics (SAUM) workshop was a laser beam focused on assessment appropriate for our purposes (Madison, 2005). Our college supported travel to and from the workshop for a faculty team, and the National Science Foundation grant that funded SAUM covered the remaining expenses. Workshop participants spanned the spectrum of experience in assessment. Workshop leaders provided the expertise and structure to motivate each team to generate at least one assessment activity to be implemented at their institution. Our assessment of student oral communication of mathematics, described later in this chapter, was a product of the SAUM workshop, and provided us with the initial success that we needed to motivate subsequent assessment activities.

At this point, it is appropriate to summarize the transition from external to internal motivation for developing an assessment program. The regional accreditation agency identified the need for the college to be accountable to students and the state and region the college serves. This accountability was to be validated by the college providing evidence of student progress and performance in meeting the college’s own stated goals and objectives. The college responded by mandating that departments develop assessment programs appropriate for each discipline, respecting the departments’ disciplinary expertise, giving the departments flexibility in developing assessment activities, and supporting departmental assessment efforts with grants and college-wide venues for presenting and discussing assessment activities. Faculty recipients of college support became the advocates for program assessment within departments. As the college community placed higher value on assessment activities, more faculty became engaged in the process.

Certainly there are other external motivations for assessment, some of which are enumerated in a variety of publications. See, for example, the volume that was produced as a result of the SAUM project (Steen, 2006). As an instance of other motivations, Keene State College has historical roots as a normal school, with a focus on producing schoolteachers for the state and region. That traditional role remains important, so meeting state and national teacher certification standards is very important. The fact that regional accrediting agencies, state departments of education, and national certifying agencies are slowly beginning to speak the same assessment language makes program assessment valued by more faculty.

Obstacles to Faculty Buy-in

Since program assessment must necessarily involve faculty, motivating faculty to do the additional work necessary to gather and analyze data is a very real issue. Attending the AAHE conference and the SAUM workshops led us to the conclusion that it was important that we purposefully design an assessment program that would get the entire department involved. What follows is a review of our initial thoughts toward obtaining faculty buy-in, our lessons learned, and ideas on that subject offered by others with experience in the program assessment process. In the compilation of ideas that follows, some sources of resistance—or the reasons why faculty will balk at participating in assessment—are described. Identification of those sources is a first step in overcoming faculty resistance. Various strategies for overcoming faculty reluctance are offered in succeeding paragraphs.

Value for Additional Work

There are various reasons why faculty may not be eager to jump on the assessment bandwagon. First and foremost, the additional work required adds to the demands on a faculty member's time. Program assessment requires serious time expenditure on the part of faculty in the development of assessment instruments, implementation of the individual assessments, analysis of assessment data, and compiling and reporting assessment results. That time and additional work does not translate immediately or in obvious ways to the traditional domains valued by academe: teaching, scholarship, and service. Many faculty question the value and effectiveness of program assessment, insisting that the status quo has worked well in the past, and there is no need to change. If assessment is perceived as a top-driven movement, faculty may feel that assessment is being forced upon them as something that is required of them by administration, which could result in a lip-service and ineffectual faculty response. Some faculty view the assessment movement as just another fad in academia, to be ignored, as it will fade with time. Because assessment focuses on the details of learning outcomes and learning objectives, many faculty believe the more important "big picture" notions will lose emphasis. Some faculty see the imposition of assessment practices as a restriction of their academic freedom to conduct classes and assess students in the manner that they find appropriate.

Additional Expenses and Academic Freedom

Administratively, there are significant expenses associated with program assessment, particularly if assessment plans include standardized examinations, such as those provided by the Educational Testing Service (ETS) (2005), or external evaluators. Even without those obvious high cost items, there are significant administrative expenses associated with the production, scoring, and analysis of assessment instruments. Finally, some faculty find program assessment to be personally threatening, fearing that assessment results could be used unfavorably in the academic promotion and tenure process or in other personnel actions.

Tactics for Overcoming the Obstacles

A wide range of methods and practices can be used to overcome the obstacles to assessment. The list that follows is not exhaustive but is the result of our experiences and contributions from others. The methods will be grouped roughly in the order that they apply to the obstacles listed above.

Minimize Time Demands on Faculty

Yes, there is no denying nor getting around the fact that assessment will require significant faculty time and effort. To minimize the demands on all department faculty, we chose to have willing faculty members do most of the work as we piloted our initial assessment effort. We assessed just one learning outcome, tied to a most important program goal, again to minimize the requirements placed on remaining faculty. The remaining faculty members participated in the process of selecting that outcome and were informed of the assessment plan, and they were content to let the detailed work be accomplished by the two assessment advocates. In the process of collecting the data for the assessment, other faculty members willingly participated in using the locally developed rubrics to score student performance, but the compilation and analysis of the data was performed by the assessment team. The team then presented the results to the rest of the department with recommendations for potential changes to our curriculum and pedagogical practices. By having two faculty members shoulder most of the work in the initial effort, the rest of the faculty was spared from having to take on significant additional work.

Another time and effort saver was that our assessment team chose to assess a learning activity that we were already practicing. Many faculty in our department have required oral presentations of students for some time; the assessment effort just formalized and documented what we were already doing. By adopting this form of embedded assessment, the work and time required of faculty was minimized. We also did not take significant additional time to develop or search for an assessment instrument, as one faculty member was already using an appropriate checklist for scoring student presentations. It should be noted that the results of the assessment included the development of an improved rubric for scoring the presentations and the need for a faculty training session prior to the presentations that would lead to more consistent scoring from one faculty member to the next. One of the important results of assessment is the improvement of the assessment process.

As a slight digression, an additional saving of faculty time can be gained by enlisting the department's administrative assistant, if the department is fortunate enough to have one. The assistant can support the assessment effort, freeing faculty from some of the administrative chores. An effective administrative assistant can compile and organize data generated within the department, and also retrieve other assessment information from the offices of institutional research, alumni affairs, the registrar, and admissions.

Focus on Student Learning

With the presentation to the department and subsequent discussion about the results and potential changes to pedagogy and curriculum, the remaining faculty began to see the value in program assessment. In the process of doing the assessment, we took the time as a department to discuss the strengths and weaknesses of our students in accomplishing a specific and valued learning objective, and the discussion was based on data and not perceptions or anecdotal information. The focus was on what students were able to accomplish, and we discussed what we could do programmatically to reinforce what we saw as student strengths. Specific ideas included revising the rubric and providing it to students prior to their presentations so that they were aware of faculty expectations and points of emphasis, using the rubric (with faculty-dependent variations) across the spectrum of our courses for consistency, requiring student presentations in courses normally taken by first- and second-year students to increase their comfort level with the oral communication of mathematics as they practice early and often in our program. Less formal oral communication, such as students presenting homework exercises, students making relevant presentations on the history of mathematics, and students teaching course topics, were discussed and advocated. The discussion about the results of the initial assessment warmed faculty skeptics to the benefits of assessment. That discussion was focused on whether or not our students had learned to communicate mathematics effectively. It became apparent that the assessment was about student learning, and faculty realized that the process does indeed lead to improved student learning.

Lessons Learned

To summarize, lessons learned from our initial assessment experience that helped obtain faculty acceptance include the following.

- Start the assessment process on just one student learning outcome clearly linked to a program goal.
- Conduct the initial assessment on a topic that is valued by most or all department faculty.
- Keep the initial assessment simple and relatively “pain free” for most of the department.
- Keep the rest of the department informed about the progress and results of the assessment.
- Keep the assessment activity on the department meeting agenda continuously.
- Be honest and open with faculty colleagues in the presentation and analysis of the results.
- After the assessment data are collected and analyzed by a faculty team, let the department decide through consensus whether change is needed and what change to make.
- Complete the assessment cycle on the one learning outcome, even if it means no program changes are necessary.
- Sell assessment as a vehicle for improving student learning.

Assess What Faculty Value

At the conclusion of the initial assessment discussion, the department, not the assessment team, decided the next program goals to assess. In that way the rest of the department declared ownership of the assessment process. It was helpful to suggest assessment topics that were known to be “near and dear” to particular faculty members as a way of winning their support. In our case, the assessment advocate participated in the early stages of a subsequent assessment activity but assumed a minimal role as other faculty took charge of the assessment process for the learning objective that was important to them.

It should be noted that within our department, we chose what to assess, how to do the assessment, and what we were going to do with the results of the assessment. This internal implementation was our response to the external mandate. Because we took charge of the assessment process, doing it our way, the external charge to assess our major became more palatable. Additionally, an intentional emphasis on conducting the assessment in a personally non-threatening way removed the anxiety that some associate with assessment, particularly if assessment is seen as controlled rather than internally within the academic department.

Develop Faculty Assessment Teams

Because the external mandate was communicated through department chairs, and because department chairs at our college do almost all the administrative work in the departments, our department chair has always been involved in the assessment process. The SAUM model of having an assessment team of at least two faculty members is very important for the success and efficacy of the assessment process. Two people working together will have more success advocating assessment to others in the department. Additionally, two working together will be able to discuss and develop more effective assessment plans than a faculty member working alone. In an ideal world, those members should not include the chair, as the chair usually has too many other duties to contribute effectively to the assessment effort. Having the support of the chair is essential, but that should come naturally at most institutions as chairs will be aware of the importance of assessment because of institutional pressure from the administration. Additionally, the assessment team should not include untenured junior faculty, unless the assessment work will count significantly in the promotion and tenure process. Junior faculty should focus on establishing a solid scholarship program, and the time it takes to do the assessment work would detract from scholarly efforts in the discipline. Occasionally the assessment work can be turned into scholarly publication, which, as this volume exemplifies, can happen.

Obtain Consensus with Broader Issues

One of the initial activities in the assessment process is to develop or consult the department mission and program goals (Gold, Keith, & Marion, 1999). Our mission and goals can be found in Appendix A. In addition to paying heed to foundational features of mission and goals, developing department cohesion through consensus building on these “big picture” issues is often easier than on later assessment details. Most faculty will agree on what is most important for students when considering more general notions. Department cohesion and consensus on the big picture will be important for the subsequent, more detailed work of identifying student learning outcomes to be assessed consistent with department goals. Our department mission was initially drafted to be consistent with our college mission, and the program goals were an adaptation of the work of others (Colorado School of Mines, 2005), publicly available via a web search.

Use Assessment to Validate Need for Curricular Change

An individual faculty member in our department wanted to ensure coverage of specific topics in one course in our curriculum and was concerned that others teaching that course were not emphasizing those topics sufficiently. That faculty member boarded the assessment train after we demonstrated that assessment activities attending to those topics would get the department focused on those specific topics and would provide data for how well students are learning those topics. Program assessment can, and should, be used to justify desired program change. Assessment methods can provide the data necessary to provide a sound rationale for change, rather than relying on personal perceptions and anecdotal information. If a faculty member has a particular concern about the department program, assessment can be used to help that faculty member address that concern.

Additional Ideas to Increase Faculty Involvement

Finally, here are some other tactics to get the department immersed in the assessment process:

- Conduct periodic department assessment retreats. A short meeting is probably not the appropriate forum to discuss assessment with any effectiveness. Longer meetings of several hours duration are needed to work through the detailed issues involved with program assessment. Obtaining support from college administration for a department assessment retreat, held on or off campus, should be available, particularly if administration is requiring the department to provide assessment results.

- Get more faculty involved. As the assessment program matures, faculty other than the assessment team can be eased into the assessment work. Teams can be solicited and formed to do portions of the assessment. For example, if an assessment survey is part of the process, a team can be asked to do the work of compiling and presenting the results to the department with recommendations. That effort would only take a few hours work on the part of that team and get them engaged in the process. Another example is to have a team develop a rubric for assessing a particular learning outcome that the rest of the department employs. Again, this relatively small task gets more people involved in the assessment process.

- Collect course-end reports. Another way to get every faculty member involved is to establish a program of course-end reports completed by each instructor of each course. That report could be as simple as the individual faculty member’s reflections on the success of students in meeting course objectives, with comments on what practices should be continued (what worked) and what should be modified (what did not work so well).

The goal in adopting any or all of these tactics is to create an assessment culture, one in which program assessment is adopted as a way of life within the department.

A Summary of the Assessment Strategy

The assessment strategy described above can be summarized as a *crawl, walk, run* approach. The *crawl* phase is the initial effort, well-planned to be successful. The *walk* phase includes involving more faculty in the assessment work and informing all faculty of plans, data analysis, and recommended curriculum changes. You will know that your department is in the *run* phase when program assessment activities are common practice, assessment results are routinely used to justify program changes, and it is obvious, internally and externally, that assessment is an accepted process within the department.

Figure 1
A Crawl, Walk, Run Strategy for Obtaining Faculty Buy-in

- *Crawl*
  - Start with an important (consensus), non-threatening objective.
  - Start with a single objective and complete the assessment cycle.
- *Walk*
  - Get more department members involved.
  - Communicate plan/process/results to all.
- *Run*
  - Assessment is an accepted practice.
  - Continually implement program changes based on assessment results.

At the time of this writing, our department is in the walk phase. From the initial assessment of student oral communication of mathematics, we have gone on to assess specific skills and student ability to use technology to solve mathematical problems. Most of the remainder of this chapter will describe those processes in more detail. Additionally, we have expanded our assessment tool set to include exit interviews and surveys, which have both been useful in departmental discussions of curriculum change. We start with a discussion of the exit interviews and surveys.

Expanding the Assessment Effort

Exit interviews and surveys of graduating students can provide a department with student perceptions about the program the students just experienced. A weakness of these sources of information is that they reveal little about what students can actually do, but they are valuable in that they can identify what students *feel* they can do. In some sense, surveys and interviews provide information about student confidence in their ability to accomplish program goals. Our exit survey, administered to graduating majors, was directly linked to the program goals (see Appendix B-1).

What the survey revealed (Appendix B-1) over the last two years is that students are less confident in their ability to use technology to do mathematics than the other goals that the department values. This is an indication of an area of relative weakness in our program, an area that may require curriculum change to remedy the weakness. The information provided in the assessment process allows for data-driven or evidence-based decision making.

A couple members of our faculty had already perceived student ability to use technology to be an area of weakness. Because of that concern, our assessment effort expanded to address the technology goal after we felt we had completed the assessment cycle with the communication goal. Over the next four semesters, assessments were completed to determine student competence in using a computer algebra system (*Maple*) and/or a spreadsheet package (*Excel*) to solve mathematical problems[1]. The early results of those course-embedded assessments indicated that our upper-level students did have significant difficulties in using technology to solve and analyze mathematical problems. Those results, coupled with the exit survey results, provided the quantitative information necessary to justify curriculum change.

Convergence Begets Confidence

In studying numerical analysis, one learns about the Lax equivalence theorem, a result relating convergence and consistency of numerical methods, important in obtaining useful numerical solutions to partial differential equations. In assessment, there is a similar result: convergence begets confidence (Yancey, 2005):

> My thesis is that the degree of confidence we have in any of our beliefs largely depends upon the degree to which the different methods we use to critically assess our beliefs converge on the same conclusion. The greater the number of different sound methods of evaluation that converge on a single conclusion, the more confident we can be in that conclusion . . . . In sum, convergence begets confidence. (Barnett, 1990)

Expanding the assessment effort using multiple assessment tools is important as multiple indicators may point to an area meriting attention in the curriculum review process. Analysis of multiple measures can provide justification for making curricular and/or pedagogical changes. In our case, the faculty perception that students were relatively weak in meeting our goal that they become competent in the use of technology was supported by the convergence of the results of assessment. In the students' self-assessment, they indicated that they were weakest in that area, a result consistent with the assessment of their competence.

In a department discussion of those results, it was recommended that students should be challenged to use technology earlier and more frequently as they progress through our curriculum. Several faculty members took action on that recommendation, so much so that one student asked her instructor (paraphrased), "Did you all attend a conference on using *Excel*? We're using it in Dr. F's class and Dr. W's class and in your class… " Anecdotally, it was obvious to students that our faculty was challenging them to learn to use technology in doing mathematics.

In my class, Mathematical Modeling, I adopted a textbook (Neuwirth & Arganbright, 2004) that *required* the use of technology, different from the textbook (Giordano, Weir, & Fox, 2003) I preferred to use. I preferred the explanations of the mathematical content of the latter textbook, but in the process of reading the new book, students had to use *Excel* to keep up with the authors. The change in the text was one of several pedagogical changes for the course, which had the previously established goals that students would be able to:

- Describe the mathematical modeling process.
- Develop and implement both discrete and continuous mathematical models.
- Develop and implement both deterministic and stochastic models.
- Analyze and compare mathematical models.
- Construct and communicate mathematical models.
- Use technology to implement, solve, analyze, and communicate mathematical models.

The course goals did not change, but because of the increased emphasis on technology, course content did change. The content was commensurately reduced, as indicated in the Table 1.

It is important to emphasize that the course goals remained the same, but the emphasis shifted on how those goals were achieved. In the new course, the goals were to be attained in a technology intensive environment, one in which student preparation for class, in-class activities, and graded projects all required the significant use of technology. In the previous course, *Excel* and *Maple* were used by students in completing course requirements,

Table 1
Change in Modeling Course Content as a Result of Assessment

Course content (pre-2005)	Course content (2005):
• Modeling process • Difference equations (single and systems) • Proportionality and geometric similarity • Model fitting and criteria for evaluating models • Polynomial models and splines • Markov processes • Simulation modeling (Monte Carlo method) • System reliability • Linear regression • Linear programming • Differential equations	• Modeling process • Difference equations (single and systems) • Markov processes • Simulation modeling (Monte Carlo method) • System reliability • Linear regression • Linear programming • Differential equations

but in the new course the emphasis was on students developing a confidence and competence in their use of one technological tool (*Excel*) to solve a wide variety of mathematical problems.

To initially assess the impact of the implementation of this change, a simple survey was administered to students at the end of the semester [see Appendix C]. The results of the survey were encouraging: Students all rated their ability to use technology to do mathematics either stayed the same (3 students) or improved (14 students). It was important to note that 5 of the 17 felt their ability increased from poor to good (a leap of 2 categories). While these results are an indication that the change is having a positive effect in student confidence, further assessment is necessary to ensure that student competence is increasing as well. Have our students really learned to use technology to solve mathematical problems? It is much more difficult to develop an activity demonstrating student competence in using technology. Building on our previous efforts, work is underway to do exactly that, complete with an appropriate rubric to measure students' demonstrated capabilities.

To summarize this expansion of our assessment effort, we proceeded from an assessment of one of our program goals to assessments of more program goals. Exit surveys and interviews indicated that students perceived their ability to use technology to be relatively weak, and the convergence of those results with the results of our assessment of upper-level students' use of technology indicated the technology area was ripe for curriculum change. As a result, faculty emphasis on the student use of technology increased and not surprisingly, student confidence in their use of technology subsequently increased. A more longitudinal and consistent effort is needed to determine if the increase is sustained or at least made stable. Assessment of student competence in the use of technology remains to be accomplished. Additionally, we are investigating the value of nationally-normed instruments, such as the Educational Testing Service's Major Field Test (2005) in mathematics, as a way to assess more broadly our students' comparative mathematical competence.

External Obstacles to Completing the Assessment Cycle

Before concluding, I would be remiss in not reporting a significant difficulty encountered in our attempts to complete the assessment cycle. Our department chose to assess the mathematics skill goal after completing the cycle with the communications goal. More specifically, we chose to assess our students' ability to evaluate two derivatives involving straightforward applications of the chain rule and two integrals involving similarly fundamental substitutions. The assessments were course-embedded in both lower level and upper level courses predominantly populated by mathematics majors. We found student performance on the calculus skills assessments was unsatisfactory, and consistently so over several semesters. Assessment is about student learning, and our assessment revealed that many students were not retaining expected skills. These results indicated that we needed to change our practices, and the approach that we decided upon involved the introduction of computer-based fundamental calculus skills tests in our calculus sequence.

We have not been able to devote the time and effort necessary to develop and implement those tests, the change in our practices that we hope would remedy the student learning deficiency identified in the assessment process. Higher priority, externally imposed requirements that demanded significant faculty input—a certification visit by the State Department of Education assessing the college's teacher education program, the revision of our college general education program, and the college-wide transformation to a four-credit based curriculum from a three-credit based curriculum—kept us from completing the assessment cycle with this goal. Our experiences in the assessment process have helped our department work toward completion of those initiatives and have informed our decision-making in those areas. But college-wide, the momentum for program assessment has slowed as we tackle the larger and more pressing issues. Each of our faculty teach a 12-credit load each semester, and teaching is priority one, much higher than program assessment, at our college. An additional factor is that, in the past five years, we have had four different persons serving as Vice President of Academic Affairs, a key leadership position influencing academic priorities. While our program assessment continues, environmental and cultural impediments have affected progress. All departments undertaking program assessment must be realistic about how environmental and cultural obstacles could influence their assessment activities.

Summary and Concluding Comments

The purpose of this chapter is not to flaunt our successes or excuse our failures with program assessment, but to share our experiences so that others may benefit. Effective assessment cannot be accomplished without significant institutional support, and that support is manifested by the allocation of resources to support faculty professional development in the area of program assessment and by the purposeful creation of a campus culture in which program assessment is valued and beneficial to students and faculty alike. Some of the reasons that faculty resist include the additional time demands of assessment, the perception that assessment results could be personally threatening, and the simple fact that the pain of changing teaching practices caused by assessment is not worth the gain.

But the gain is an improvement in student learning, and if assessment is implemented so as to demonstrate the benefit to student learning, faculty who care about students will embrace program assessment. The *walk, crawl, run* approach to implementing assessment described above is a slow process, but cultural change, and changing human behavior, is a long, slow process that merits patience. After first assessing the fertility of the institutional environment, advocates for assessment can develop an appropriate expectation for how quickly their efforts to grow an assessment program will bear fruit.

Endnote

1 Maple is a software package produced by Maplesoft and issued for mathematical exploration, visualization, and problem solving. Maple has the capability to symbolically perform mathematical operations that students in the past did “by hand.” Excel is a spreadsheet applications software package, produced by Microsoft and bundled with the popular Microsoft Office suite, which can be used for data visualization, mathematical modeling, and the analysis of those models.

References

Barnett, R. E. (1990). *The virtues of redundancy in legal thought.* Retrieved July 18, 2005, from http://randybarnett.com/38cleveland153.html#ii

Colorado School of Mines Mathematics and Computer Science Department. (2005). *Department goals and objectives.* Retrieved July 14, 2005, from http://www.mines.edu/Academic/assess/Goals.html

Educational Testing Service (ETS) Major Field Tests. (2005). Retrieved July 20, 2005, from http://www.ets.org/hea/mft/

Giordano, F., Weir, M., & Fox, W. (2003). *A first course in mathematical modeling* (3rd ed.*).* Belmont, CA: Brooks-Cole.

Gold, B., Keith, S. Z., & Marion W. (Eds.). (1999). *Assessment practices in undergraduate mathematics*. Washington, DC: Mathematical Association of America.

Madison, B. L. (2005). *Supporting assessment in undergraduate mathematics*. Retrieved July 20, 2005, from http://www.maa.org/saum/

Neuwirth, E. & Arganbright, D. (2004). *The active modeler: Mathematical modeling with Microsoft Excel*. Belmont, CA: Brooks-Cole.

Steen, L. A. (Ed.). (2006). *Supporting assessment in undergraduate mathematics*. Washington, DC: Mathematical Association of America.

Yancey, K. B. (2005). [Talk given at SUNY general education assessment conference]. Syracuse, NY.

Appendix A: Department Mission and Goals of the Majors Program

In keeping with the mission of the college, the Mathematics Department of Keene State College provides and maintains a supportive intellectual environment that offers students mathematical experiences appropriate to their individual needs and chosen programs of study. The department provides an in depth study of mathematics in preparation for either an immediate career, especially teaching, or graduate school; supports the mathematical needs of other academic disciplines; and maintains a program available to all students to enhance their ability to think mathematically and to reason quantitatively.

Goals in support of the major:

Students will possess:

- Technical skill in completing mathematical processes;
- Breadth and depth of knowledge of mathematics;
- An understanding of the relationship of mathematics to other disciplines;
- An ability to communicate mathematics effectively;
- A capability of understanding and interpreting written materials in mathematics;
- An ability to use technology to do mathematics.

Appendix B-1: Exit Survey

Please rate the extent to which you possess the following by circling the corresponding number.

a. Technical skill in completing mathematical processes

1 (very little) 2(some) 3 (good) 4 (great)

b. Breadth and depth of knowledge of mathematics

1 (very little) 2(some) 3 (good) 4 (great)

c. An understanding of the relationship of mathematics to other disciplines

1 (very little) 2(some) 3 (good) 4 (great)

d. An ability to communicate mathematics effectively

1 (very little) 2(some) 3 (good) 4 (great)

e. A capability of understanding and interpreting written materials in mathematics.

1 (very little) 2(some) 3 (good) 4 (great)

f. An ability to use technology to do mathematics.

1 (very little) 2(some) 3 (good) 4 (great)

Which of the above (**a** through **f**) do you possess to the greatest extent?

a. b. c. d. e. f.

Which of the above do you possess to the least extent?

a. b. c. d. e. f.

On a separate sheet or on the back of this survey, please comment on your competence on any or all of the areas a through f above.

Appendix B-2: Exit Survey Items with Average Student Ratings

				score 2004	score 2005
a. Technical skill in completing mathematical processes					
1 (very little)	2(some)	3 (good)	4 (great)	**3.5**	**3.45**
b. Breadth and depth of knowledge of mathematics					
1 (very little)	2(some)	3 (good)	4 (great)	**3.25**	**3.20**
c. An understanding of mathematics and its relationship to other disciplines					
1 (very little)	2(some)	3 (good)	4 (great)	**3.625**	**3.35**
d. An ability to communicate mathematics effectively					
1 (very little)	2(some)	3 (good)	4 (great)	**3.25**	**3.25**
e. A capability of understanding and interpreting written materials in mathematics.					
1 (very little)	2(some)	3 (good)	4 (great)	**3.125**	**3.25**
f. An ability to use technology to do mathematics.					
1 (very little)	2(some)	3 (good)	4 (great)	**3.125**	**3.05**

Which of the above (**a** through **f**) do you possess to the greatest extent?

	a.	b.	c.	d.	e.	f.
2004	2	1	2	2	0	1
2005*	4	2	4	1	1	1

Which of the above do you possess to the least extent?

	a.	b.	c.	d.	e.	f.
2004*	2	0	0	1	2	4
2005*	0	2	3	3	2	2

*Note: The numbers do not add up as students made multiple entries (1 in 2004 and 3 in 2005)

Appendix C: Technology Survey

On the following scale, how would you rate your ability to use technology to do mathematics before you took this course?

0 (none) 1 (poor) 2(weak) 3(good) 4(great)

Comments:

On the following scale, how would you rate your ability to use technology to do mathematics as a result of taking this course?

0 (none) 1 (poor) 2(weak) 3(good) 4(great)

Comments:

Of what value was the textbook as an aid in supporting your learning of mathematical modeling in this course?

00 * 0 (none) 1 (poor) 2(weak) 3(good) 4(great)

00* —don't know, I never used the book!

Comments:

CHAPTER 5
ASSESSMENT IN MATHEMATICS: A COLLEGIAL EFFORT

Susan Pustejovsky
Alverno College

Introduction

Any story about assessment of student learning in mathematics courses at Alverno has necessarily an arbitrary beginning, because the process has been ongoing for many years. This chapter is the personal experience of the author during the past 15 years. During these years my colleagues and I have worked together to articulate a common understanding of the work of assessing student learning in mathematics; this understanding continues to evolve, structuring our tasks as a department and our work as individual faculty teaching courses. This narrative provides some examples of assessment of student learning in mathematics courses such as trigonometry, precalculus, and calculus, and suggests some ways that these activities form part of a larger system.

College-wide competencies, called *abilities*, frame assessment of student learning throughout our curriculum.[1] Alverno's *abilities—communication, analysis, problem solving, valuing in decision-making, social interaction, developing a global perspective, effective citizenship,* and *aesthetic engagement*—were identified over thirty years ago by the faculty as broad descriptions of what students should learn in order to graduate. Within courses, these student learning goals are integrated with disciplinary content, so that courses in particular departments tend to focus on just a few of them. In mathematics courses, we teach and assess three *abilities* in particular: *problem solving, analytic thinking,* and *communication.*

College-wide, faculty have worked together to articulate levels of the *abilities*, creating a common language and structure which we all understand and use to teach and assess student learning. For example, *analysis* and *problem solving abilities* can be briefly and generically articulated in beginning and intermediate levels (Loacker & Rogers, 2005, pp. 27-28):

Analysis means that the student:
1. Observes accurately.
2. Infers from observations.
3. Makes relationships.
4. Analyzes structure, synthesizes parts.

Problem solving means that the student:
1. Articulates problem solving process.

2. Practices using standard discipline problem solving processes effectively.
3. Formulates, solves problems, interprets results.
4. Formulates problems, selects problem solving approach, interprets results, evaluates process.

Course content and *abilities* are intertwined. As a new faculty member in 1991, I had to learn how *abilities* fit into teaching mathematics. Further, the Mathematics Department had adopted guiding learning goals in "Outcomes for the Mathematics Major." How would these help me teach calculus or differential equations? What I have come to understand in the intervening years is that program outcomes (college-wide and departmental) form the framework of everything we do with students, and underpin all course learning goals, assignments, and evaluations of student learning.

My first task in 1991 was to learn to teach the courses I was assigned: a reform calculus course involving computer laboratory experiences called Project CALC[2] and an upper level differential equations course. I knew that I was supposed to teach *problem solving, analytic thinking,* and *communication* as well. But how would I make judgments about whether the students had met these learning goals by the end of the semester? My colleagues helped me to articulate criteria for student achievement of the course goals and to learn how this system—clearly stated learning goals, public criteria for achievement, and feedback to students—supports student learning and accountability.

Instruction for Outcomes – Using Student Learning Goals

Implementing the reform calculus ideas—structuring class time in a new and different way and reflecting on what students needed to do in class—along with teaching the *abilities* required better articulation of what it was I wanted students to know and be able to do. The Mathematics Department chair at the time dedicated some of our regular department meeting time (approximately two hours every two weeks) to structured conversations about the mathematics learning outcomes. We rewrote the outcomes for the mathematics major, finalizing them in the following form (Alverno College Mathematics Department, 2005):

An Alverno graduate with a mathematics major:

1. Reads, writes, listens, and speaks mathematics effectively.
2. Uses the language, frameworks, and processes of mathematics effectively.
3. Formulates and solves diverse mathematical problems and interprets results.
4. Uses mathematical abstraction.[3]

Clearly, these are connected to many of the college-wide *abilities* (*communication*, *problem solving*, and *analysis* in particular), but go further to describe what a graduate should be able to do within our discipline. These statements may sound abstract and general; however, they grew out of our experience and our concrete common understanding of what is important in mathematics learning. We developed these common understandings in a collaborative process that involved describing our various courses, the students typically in these courses, the learning experiences we had developed for students, and the evaluative assessments we used.

The outcomes statements formed a framework to help me think about my own courses and how they fit into helping students learn and develop toward a final goal at graduation. One implication of this framework emerged immediately: The role of coursework is to help students develop the capacity to demonstrate the outcomes for the mathematics major and the college's *abilities* at the end of their program. We can picture students growing toward demonstrating outcomes, so we can articulate incremental steps along the way. Any particular course should build on the work of other courses, both in mathematics content knowledge and on the way students have been asked to use their knowledge.

Outcomes influence the nature of all mathematics courses, not merely courses for the major, because they form a framework for thinking about the broad learning goals for any course. Students from many majors populate courses such as trigonometry, precalculus, and calculus; but overarching mathematics learning goals for mathematics are the same for all, at that level, in that particular course.

Calculus Reform

In 1991, the reform calculus course I was to teach differed greatly from anything I had previously taught. The Mathematics Department had decided to become a test site for the reform Project CALC before I arrived, noting that the student learning goals of the project strongly agreed with their pedagogical philosophy, learning outcomes and the college *abilities* – a focus on reading and writing, an emphasis on active learning, and the centrality of problem solving. In the beginning, I relied heavily on the instructor's manual, faculty workshops, background papers, and the expertise of the authors. The national discussion about teaching calculus helped articulate learning goals for the course and plunged me, as instructor, immediately into the problems of evaluating student achievement in ways that addressed the project work and problem solving in the course.

Calculus 1 is a beginning level course for mathematics and science majors. Our department decided that learning calculus requires at least intermediate levels of *problem solving, analytic thinking,* and *communication*, as defined in our college-wide *abilities*. For students to learn, practice, and demonstrate these *abilities*, they engage in substantial problem solving projects, for which they submit formal written reports. An example project illustrates that the learning goals for the course frame the assignments and how they are assessed. Selected course outcomes as stated in the Calculus 1 syllabus (Pustejovsky, 2005b, p. 4) are displayed below.

Students will:

- Read, write, and communicate mathematics effectively.
- Work independently and collaboratively to understand and usefully formulate problems using functions and derivatives or antiderivatives, especially to:
  - Express relationships between quantities using functions.
  - Conceptualize motion events in terms of displacement, velocity, or acceleration.
  - Analyze function behavior using derivatives.
- Apply a variety of calculus problem solving approaches and techniques accurately and efficiently.
- Develop persistence and confidence in mathematical problem solving situations.

The course learning goals are clearly related to the major outcomes, aiming students toward developing those outcomes from the beginning of the course.

The air traffic control problem, adapted from Project CALC (Smith & Moore, 1996), serves as an example of a substantial problem solving project. In this project, students are presented with a situation in which two airplanes, traveling at different constant speeds, move along different straight-line paths toward a common path intersection point. Student teams work to develop a model for this motion that enables them to predict the rate at which the airplanes move toward each other at any given time, how close the airplanes come to each other (do they crash?), and how long it takes to reach the time of closest approach. This problem is similar to many standard calculus problems (optimization and related rates); however, when presented outside the context of a particular textbook section, it can appear quite unfamiliar to students. Student teams are guided through stages of solving this problem and writing their solutions in a formal paper. Written solutions must reference calculus ideas and explain how the solution is obtained using derivatives.

As students solve this problem and write their solutions, they are working toward demonstrating higher levels of problem solving—formulating a model and using it to answer questions. As they prepare for the project, students learn the process of solving standard calculus optimization problems, and learn to apply the mathematical problem solving framework developed by G. Polya (1957), which then structures the written presentation of the solution. The project and its written solution become both an opportunity to further consolidate their learning and an assessment of what they have learned. The solution paper is guided and evaluated based on criteria taken from the course syllabus (Pustejovsky, 2005b).

Criteria for written solution to air traffic control problem
A successful paper meets these criteria.

1. *Organization* of the paper is clear and presentation follows conventions of written English. Use the problem solving framework to think about the organization of your paper. Suggested subsections of your paper are:

   Understand the problem.
   Restate the problem in your own words. Include labeled diagrams or thinking aids you used to clarify understanding. Define variables, label graphs.

   Describe the plan.
   What was your overall plan for solving the problem? State specific problem solving goals, both intermediate and global.

   Carry out the plan.
   Describe how you solved the problem and answered the questions. Include sufficient detail to help your audience understand and be convinced by your solution.

   Look back.
   How did you know your answer was correct? Did you use multiple approaches to the problem to check your answer? Your numerical results should be interpreted in the context of the problem. Did you answer all questions?

2. *Explanations* of reasoning, problem solving process, and thinking are included.
   You may even want to describe approaches you attempted to use that did not work and how you knew they did not work.

3. *Mathematics is correct*.

4. Numerical *results are interpreted* in the context of the problem.

Often this project constitutes students' first successful efforts to think through and solve a complex mathematics problem. The results can have enormous effect on students' confidence. Because research on mathematical problem solving shows that self-monitoring and reflection are features of expert problem solving (Schoenfeld, 1992), students answer self-assessment questions at various stages. For example, at an early stage of the project, students write answers to this request: "Describe your approach to thinking about this unfamiliar problem. Do you like to think first and then talk with your team? Or, do you more easily figure out what you think by talking?" Such questions grow out of Alverno's level 1 description of problem solving. The project's final stage reflection includes such questions as "What did you learn about mathematical problem solving through this project? If there were negative aspects of this problem solving experience overall, describe them. Can you think about changing something you do to make the next experience different? Describe at least one positive aspect of this problem solving experience overall (for you). Be specific." Students' own reflections coupled with feedback from me move them toward developing persistence and confidence in problem solving, one of the expected outcomes for Calculus 1.

The positive results of this particular project (air traffic control) on student learning and the positive self-awareness that I have read in students' reflections have led me to view this project as a key to success in Calculus 1. The problem itself is not especially unusual, but it requires students to go through all steps in a process, from formulating a model to interpreting results. Repeated use of this or similar problems has led to a refined sequence of stages with intermediate reflections by students. The final reflection becomes a part of students' digital portfolios (described below) as representative of one stage in their development as mathematical problem solvers.

Courses before Calculus

Our departmental work has evolved continuously to meet the changing needs of students in our courses and the needs of teaching mathematics in a changing environment. For example, using calculus reform ideas to help more students learn calculus successfully and meaningfully in the early 1990s was clearly consistent with the college's *abilities* and the learning goals articulated by the Mathematics Department. As in many institutions, calculus reform was the first step in many changes undertaken later, including revising courses leading to and following the new calculus.

We found that many of our science majors needed a stronger preparation for calculus. Many begin with College Algebra and Trigonometry, followed by the three-credit Functions and Modeling course, which itself was a revision of the former two-credit Precalculus course. This revision stemmed from the need for a more substantial course, one designed to help students consolidate their algebra knowledge, develop a stronger understanding of the multiple representations of functions (especially graphs), and to conceptualize functions as models for realistic phenomena —a strong perspective in the calculus course. The new Functions and Modeling course was also designed to strengthen the minor for elementary education majors as a stand-alone course while it served as preparation for calculus for others.

Expressed in the language of levels 1–3 of *analysis*, students need to "observe, infer, and make relationships" in the mathematics they are learning. Similarly, levels 1–3 of *problem solving*, "articulate problem solving process" and "use standard discipline problem solving processes effectively," are appropriate to the content of this course and the students who typically take it. Student learning goals for the course are clearly stated in the syllabus for the Functions and Modeling course (Pustejovsky, 2005a); for example:

Student learning outcomes are related to *communication, analysis*, and *problem solving*. By the end of this course, students will:

- Demonstrate fluency in the use of mathematical symbols, the language of functions, function composition and function inverses, and in the interpretation and creation of graphs.

- Apply analytic reasoning to make explicit connections among graphical, symbolic, and tabular representations of functions.

These learning goals integrate knowledge of mathematics and the ability to use it. A problem from a typical assignment asks students to sketch accurate graphs of linear and quadratic functions, use algebra to find all important intercepts and intersection points exactly, and explain how the algebraic procedures are related to the graphs they have sketched. Students' explanations reveal whether they are able to make explicit connections among graphical and symbolic representations of functions. Feedback can help them make these connections explicit. Typically, students in this course plan to go on to take calculus and other mathematics courses necessary for their majors (such as biology), or they are future elementary teachers with a minor in mathematics. Such assignments can help students develop a connected knowledge of mathematics, knowledge they are able to use in future courses or in their teaching.

A second example, from Trigonometry, illustrates the design of learning experiences aimed at teaching *analysis* and *problem solving* at beginning levels within a mathematics course. Joint discussions among science and mathematics faculty revealed common difficulties in problem solving situations in many beginning mathematics and science courses. Some of these common difficulties are:

- Identifying the actual question asked and what a potential answer might look like;
- Keeping track of thinking in a multi-step problem solving process;
- Getting so involved in computational details that the "big picture" is lost; and
- Failing to use diagrams or visual representations to help them think about the problem.

Beginning students in science as well as mathematics need to develop independence in creating visual representations of problems. Often students come to us in a "formula-ready" mode—they think they simply need to learn computation procedures for success in mathematics and science problem solving situations. We seek to move beginning students beyond this stage.

To address these aspects of mathematics and science thinking in trigonometry, students work regularly on problems requiring them to generate appropriate diagrams and use them in understanding, solving, and reflecting on the problems. Students write formal solutions (in complete sentences); writing criteria guide them to explain the problem, explain their solution, integrate diagram(s) in their explanation, and interpret the mathematical solution in terms of the original question in the problem. Since the problem solutions require elementary mathematics and more than one step in a problem solving process, such work elicits performances of all three *abilities* taught in mathematics courses: *analysis, problem solving* in the context of trigonometry, possibly pushing toward level 3, and integrated written *communication*. The writing criteria help students improve their problem solving performance by making them explicitly aware of all phases of the problem solving process. Feedback is based on criteria, and students have multiple opportunities throughout this course to practice.

Technology

The calculus reform decision also led to rethinking classroom technology needs. One Mathematics Department outcome, "Uses the language, frameworks and process of mathematics effectively," includes the ability to use and adapt computational tools to assist in effective problem solving. The need for updated computational tools and an environment in which to teach toward this outcome led to a successful application for a National Science Foundation (NSF) grant in the early 1990s to fund the college's first classroom-computer laboratory, in which students could work with the specialized mathematical software required by the Project CALC laboratories.

Conversations with our science colleagues and feedback from students led to a decision to use calculators and Excel spreadsheet software as our primary computational tools. In chemistry and biology (the majors served by calculus), students were using Excel for computational purposes, and science faculty convinced us that it would be helpful to students if they encountered the same tool across many courses. As computation power grew and became more available, many students in Calculus 1 used graphing calculators with computer algebra systems, so our current tools consist of the ubiquitous Excel and more powerful calculators.

Overall, interaction with science colleagues has strongly shaped our thinking about the nature of student work in mathematics courses.

Current Work and Next Steps in Assessing the Mathematics Major

Currently, our department is formalizing assessment of individual student learning and organizing it to be more easily accessible across a student's set of courses. This helps the student and us detect patterns of strengths and weaknesses and to document development toward demonstrating program outcomes. An electronic portfolio system, linked to college-wide *abilities* and learning outcomes in majors, has been created, and faculty are now learning how to use portfolios to document individual student learning and achievement and to detect patterns within entire programs.

A student's digital portfolio is not merely an electronic repository for all of a student's work. Rather, selected pieces of student work are entered together with a description of the assignment, the assignment's criteria, faculty feedback, and the student's own self-assessment. An example entry in the student's portfolio (called a "key performance,") is the Calculus 1 air traffic control project. An important goal of the digital portfolio is to help students understand patterns in their own learning. The reflection about the air traffic control problem solving is designed to help a student record and remember an early stage in her mathematical problem solving development. Other entries from more advanced courses will represent later stages of her mathematical problem solving achievement.

The Mathematics Department plans to develop a "proof" strand as well as a mathematical problem solving strand—a sequence of key performances reflecting students' growth over the course of her studies. Formalizing these within students' digital portfolios will require collaborative work within the department. As they use their portfolios, students will be able to plan for their own growth. The department will be able to see patterns of performance across courses.

Using the portfolio system to gather information relevant to program assessment is current work. This work is partially supported by a three-year grant from the NSF Assessment of Student Achievement program to our Division of Natural Sciences, Mathematics, and Technology.

Program evaluation in the Mathematics Department in earlier years had been informed by the then departmental practice of informal exit interviews of graduates. We plan to reinstitute the exit interview in more formal form as a key performance in a mathematics major's digital portfolio. In a written reflection to prepare for an interview with faculty, a graduating student will examine her growth during her years at college, her particular strengths and interests, and discuss how she has demonstrated the outcomes for the mathematics major. The digital portfolio provides evidence in the form of key performances supporting her reflection. It can also provide material to easily create a showcase portfolio containing examples of her best work.

Summary

Teaching and reflecting at Alverno College these past 15 years has enlightened me significantly about learning and assessment. Threaded through all my experiences is the importance of my interaction with my students and my colleagues. Collegiality and coherence are critical contributors to the lessons learned, some of which are summarized below.

Frameworks are Essential, but Require Discussion

An educational and professional environment focused on assessment of student learning already existed at Alverno when I joined the faculty. Curricular and assessment frameworks existed; however, I needed to make sense of them for myself, just as our students need to build their own understanding of mathematics concepts. Departmental and cross-departmental conversations about the meaning of the frameworks, illustrated with examples of assignments or projects that students complete within courses, were essential. Discussion helped to foster concrete understanding of what kinds of learning students experienced -– both before and after courses I taught.

The writing activities our department undertook to articulate our program outcomes, such as rewriting the Outcomes for the Mathematics Major when I first arrived, and the work we did to produce the Description of the Mathematics Major (Alverno College Mathematics Department, 2005) were crucial activities in helping all mathematics faculty understand all our courses and their role in our program. These activities were key because they produced written documents on which we had to agree and also because the process of writing them entailed continuing, in-depth discussion among faculty about the work that we do to teach our courses.

Program outcomes together with college-wide *abilities* form the very basis for our work as instructors. These larger frameworks help us choose and clearly express learning goals for each course and for assignments within courses. Learning goals, and criteria by which to judge student achievement, enable us to give informed feedback to students to help them to grow in knowledge, skill, and disposition.

Student Learning is Developmental

A fully sequenced program for a major that students step through in a completely structured order is impractical at many institutions. More flexibility is needed, especially at smaller institutions. We have found it useful to think about groups of courses in terms of beginning, intermediate, and advanced levels, and to elaborate what mathematical *problem solving, analytic thinking,* and *communication* should look like at each level. This approach helps us think about each course as part of a larger, coherent program, and think about students in the course as developing these *abilities* at a particular level. It also helps us identify what levels of the *analytic thinking, problem solving*, and *communication abilities* belong with a course. Expectations of *analytic thinking* ability, for example, may differ in different courses, and not just because the contents of the courses are different.

With program outcomes guiding our work, we can design learning experiences and assessments within courses for the "steps along the way" to becoming a college graduate with a mathematics major.

Feedback is Essential—Self-Assessment Can be Fostered

Using clearly stated criteria to make judgments about performances enables focused feedback to students about the important parts of their work—what they did well, and what they need to work on. Feedback is essential for learning, and effective feedback is promoted by carefully designed criteria or rubrics that describe student performances. As students progress through the curriculum, they develop an appreciation of the statements of performance criteria accompanying major assignments and assessments and are able, with practice, to make judgments about their own work.

Courses are Part of a System

Systems theory and practice tells us that making a change in one part of an interacting system changes the whole system. Mathematics faculty members are more effective as part of a system instead of acting alone. Without the continuous stimulating interaction I have had with colleagues, my work would not be nearly so interesting or rewarding. More importantly, assessment of student learning within an entire program is impossible without agreement on learning goals and how they are expressed, and without continuing conversations about the work of teaching mathematics, the central focus of our time and intellectual energy.

Endnotes

1. A detailed description of these abilities with articulated developmental levels can be found in Loacker & Rogers (2005), 27-30.
2. Project CALC: Calculus as a laboratory course was the name of the award-winning, National Science Foundation calculus reform project directed by D. A. Smith and L. C. Moore at Duke University. Textbooks associated with this project are The calculus reader (1993), and later, Calculus: Modeling and Application (1996).
3. A more detailed version of these outcomes can be found in the Appendix.

References

Alverno College Mathematics Department. (2005). *Advanced outcomes for the mathematics major.* Milwaukee, WI: Alverno College Institute.

Loacker, G., & Rogers, G. (2005). *Assessment at Alverno College: Student, program, institutional*. Milwaukee, WI: Alverno College Institute.

Polya, G. (1957). *How to solve it: A new aspect of mathematical method* (2nd ed.). Princeton, NJ: Princeton University Press.

Pustejovsky, S. F. (2005a). *Instructional syllabus, MT 148 functions and modeling*, *course outcomes* (Summer 2005). Alverno College, Milwaukee, WI: Author.

Pustejovsky, S. F. (2005b). *Instructional syllabus, MT 152 calculus 1*, *course outcomes* (Fall 2005). Alverno College, Milwaukee, WI: Author.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334-370). New York, NY: Macmillan.

Smith, D. A., & Moore, L. C. (1993). *The calculus reader, volumes I, II, and III, revised preliminary edition.* Boston, MA: D.C. Heath and Co.

Smith, D. A., & Moore, L. C. (1996). *Calculus: Modeling and application.* Boston, MA: D.C Heath and Co.

Appendix

Advanced Outcomes for the Mathematics Major (elaborated version)

An Alverno graduate with a mathematics major:

1. **Reads, writes, listens, and speaks mathematics effectively.**
   She understands and independently uses mathematical language and representations with fluency in order to communicate to varied audiences at appropriate levels.

   She creates mathematical representations in order to express mathematical structure of problem contexts and to solve mathematical problems.

   She translates among various mathematical representations.

2. **Uses the language, frameworks, and processes of mathematics effectively.**
   She applies knowledge of mathematical problems and problem solving strategies with confidence and creativity.

   She understands, uses, and adapts mathematical processes with efficiency.

   She understands, uses, and adapts computational tools to assist in effective problem solving.

   She has built and uses an integrated knowledge of mathematical frameworks, including conceptual understanding, procedural skill, and the ability to use the expressive power of various mathematical representations. These frameworks include: Algebra, Geometry, Discrete Mathematics, Functions, Calculus, Statistics, Computing, and History of Mathematics.

3. **Formulates and solves diverse mathematical problems and interprets results.**
   She integrates knowledge of mathematical and general problem solving approaches to design effective problem solving strategies.

   She formulates problems effectively based on mathematical knowledge.

4. **Uses mathematical abstraction.**
   She observes and expresses patterns, and creates generalizations.

   She understands generalizations, and expresses concrete examples.

She appreciates the power of abstraction, and the necessity of proof.

She reads mathematical proofs with understanding and insight.

She creates mathematical proofs.

CHAPTER 6
THE IMPACT OF ASSESSING INTRODUCTORY MATHEMATICS COURSES

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Introduction

The first level college-credit mathematics courses taken by students at Virginia Commonwealth University (VCU) during the thirteen-year period from 1992 to 2005 is the focus of this chapter. During this period the total enrollment at VCU increased from 21,800 to 29,000, the freshman enrollment increased from 1,500 to 2,800, and the student enrollment in mathematics courses at this level increased from 1,616 to 4,296. However, many things were the same in 1992 and 2005:[1]

- Students enrolled in sections of 30-35 students for a three-credit course;
- Students were either required to meet placement test standards or complete a course at this first level in order to enroll in a required business mathematics course, precalculus, calculus, or the statistics course required of all humanities and science majors;
- Almost all sections of these courses were taught by graduate teaching assistants, part-time adjunct instructors, or full-time instructors on appointments of limited duration.

This chapter is an account of how assessment processes were used to evaluate and modify introductory mathematics courses. The courses under consideration include traditional college algebra courses, modeling-based college algebra courses, courses aimed at quantitative literacy, and courses for business students. Student learning in these courses is assessed and compared across courses. Using this information, the VCU Mathematics Department course offerings at this level have changed significantly over the past decade and are still under study.

Background Beginning in 1992

In 1992 all entering students enrolled in a college algebra course that had the goal of increasing students' abilities to perform algebraic computations. The course emphasized adding algebraic fractions, solving equations for unknown variables, exploring exponential and logarithmic functions, and solving systems of equations. The end of each chapter of the textbook included some applications of skills the students had practiced, but these were not emphasized and were rarely tested. Computers and calculators were not utilized, but students were permitted to use graphing calculators.

Student grades were determined entirely on the basis of standardized tests. The one-hour examinations consisted of 18 multiple-choice questions and two short answer questions, often involving some graphing. Each question was worth five points.

Students were permitted to retake a different version of each test. More than half of the students were in self-paced sections, meeting three hours a week with an instructor and undergraduate assistant available to answer questions and critique tests. Attendance was required. The remaining students were enrolled in lecture sections, again meeting three hours per week. In these sections virtually all class time was dedicated to the instructor lecturing, answering questions, or (less frequently) leading a full class discussion. Most of these sections met three times a week with a class size of 35, although some met in 150-student lectures twice a week with 25-student breakout sections meeting weekly.

This was the situation in 1992 but very closely describes the course offered from 1975 through 1992.

Situation in 2005-2006

The situation in the 2005-2006 academic year is fluid; indeed, the fluid nature of these course offerings may be their most distinguishing feature. This section will provide a snapshot of the offerings for the current academic year, 2005-2006. Plans for the future and goals are described near the conclusion of the chapter.

Approximately 50% of the students who are enrolled in a course at this level—including most of those who are not required to complete a calculus course—are taking Contemporary Mathematics. The remaining students are enrolled in College Algebra with Applications which is taught with two different emphases. Twelve sections of College Algebra, enrolling approximately 420 students, are modeling-based. The other sections are closer in content and instructional approach to the course offered in 1992, although a number of innovations have occurred in this course as well.

Contemporary Mathematics Course

The Contemporary Mathematics course aims to enable students to study and comprehend quantitative situations that they have not previously encountered. The textbook is *Excursions in Modern Mathematics* (Tannenbaum, 2004) supplemented by some locally developed materials. We want students who finish this course to be able to study carefully situations that have quantitative components whether the situations arise in another college course, in daily life, or as a public policy issue. We want students to analyze the situation using their algebraic and other quantitative skills, and then explain the overall situation to others orally and in writing. In addition to taking a number of quizzes and three one-hour examinations, each student is required to maintain a Learning Log, responding to a weekly prompt; twice during the semester each student is assigned a mathematical topic to study and then is required to produce a two- or three-page typed paper explaining this mathematical situation in standard English. In addition, each student, working alone or with one other student, is required to study a new mathematical situation, prepare a poster answering specific questions about this situation, and then explain the topic to other members of the class, using the poster as a tool. Students who do not meet placement requirements enroll in a “stretch” section that has mandatory attendance requirements and meets for an extra class day with the time devoted to reviewing basic concepts.

Modeling-Based College Algebra

Modeling-based College Algebra sections were first offered in fall 2004. The sections meet four hours a week in classes of 35 students. Three of these hours are conducted in a traditional classroom and the fourth in a mathematics/computer laboratory. The course uses *Contemporary College Algebra: Data, Functions and Modeling* (Small, 2003) as a textbook. The goals are to develop problem solving abilities, provide a foundation in quantitative literacy, focus on mathematics needed in other disciplines, and meet the quantitative needs of the workplace. Students are expected to address problems presented as real world situations and then create and interpret mathematical models. In the process, students use algebraic techniques; employ linear, exponential, polynomial, radical, logarithmic, and periodic functions; and use of graphing calculators and computer spreadsheets extensively. A great deal of class time is devoted to small group exploratory activities and projects. Students are assigned two long-term projects. Approximately half of a student’s grade is based upon small group projects, homework, in-class activities, quizzes, and the long-term projects. The other half of the grade is determined by performance on three one-hour examinations and the final examination.

Traditional College Algebra

The traditional College Algebra sections also meet four hours a week. The textbook is *Intermediate Algebra* (Wright, 2004). The students are required to complete assignments generated by the course’s computer software and then to “certify” electronically that they have successfully completed these assignments. During the laboratory hours students take a short quiz and then work on exploratory activities, many of which were motivated by activities used in the modeling-based sections. The other class sessions take place in a 35-student small lecture format. In most sections the time is dedicated to instructor-led discussion, question answering and presentation of material. The goals of this course have been carefully defined and are focused on developing and honing computational skills. Grades are based upon completion of the "certified" homework, the quizzes, laboratory activities, three one-hour examinations, and the final examination. The tests consist of short constructed-answer items, not multiple-choice questions. Six sections of this course meet solely in a computer laboratory with short lectures during each class session. These sections meet three periods each week; the grading is similar to the lecture format sections except that the exploration activities are assigned as homework. As with Contemporary Mathematics, students who do not meet placement requirements enroll in "stretch" sections that meet one extra day per week and have attendance requirements.

The authors of this paper and most members of VCU's Mathematics Department believe that the current set of course offerings represents a major improvement over the offerings of the Department prior to 1993. We believe that we are closer to providing our students with the intellectually engaging mathematical experience called for in the Mathematical Association of America's Committee on the Undergraduate Program in Mathematics (MAA CUPM) Curriculum Guide (2004). We are doing this even though over 90% of instruction must be provided by graduate assistants and instructors with limited term appointments.

How We Got Here: The Assessment Cycle

In this chapter we argue that deploying the elements of an assessment cycle were necessary to achieve this change; however, before describing some highlights, two other points must be made. These changes took place during a general period of mathematical education reform and increased use of technology in both learning and using mathematics. So, some of the impetus for change was the result of this general change in climate and not directly attributable to the use of the assessment cycle. In addition, neither the department as a whole nor any individual, including the authors of this paper, declared ahead of time that all of these activities were being undertaken as part of an assessment program. However, the events that brought us from where we were in 1993 to where we are now can best be understood through thinking about four phases of an assessment cycle: (1) understanding the needs of our students and the partner disciplines; (2) designing and offering courses; (3) measuring what is happening; and (4) using this information to refine goals and courses.

Our program went through this cycle many times during this period. The story is best told by describing some of the highlights that occurred in each phase.

Phase One: Understanding Needs of Students and Partner Disciplines

The first encounter was initiated, not by the Mathematics Department, but by the Director of Advising in the English Department. Whenever she saw then Mathematics Department Chair Reuben Farley, she asked why English majors needed to develop the computational algebraic skills featured in the college algebra course. Farley had no answer to this question, but the advising director was persistent. To respond to this challenge, the Mathematics Department developed a preliminary set of goals for a new course. These goals formed the basis for formal discussions with a number of disciplines including English, history, political science, mass communications, and the arts. The discussions focused on whether these goals were consistent with the needs of students in our partner disciplines. At the conclusion of these discussions, the Mathematics Department proposed, and the university approved, the introduction of a new course, Contemporary Mathematics, with the following official goals:

- Students will be better able to think logically about situations with quantitative components;
- Students will be better able to make use of their mathematical, graphing, and computational skills in real situations;
- Students will be better able to independently read, study, and understand quantitative topics that are new to them;
- Students will be better able to explain and describe quantitative topics orally and to discuss quantitative topics with others;
- Students will be better able to explain quantitative ideas in written form; and
- Students will improve their "number sense," learn some details of a variety of situations where mathematics is used, and become engaged and have fun doing mathematics.

As an aside, we find it interesting that a few years later, a committee was formed to consider and revise VCU's general education requirements. The committee included the English Department's advising director. Ultimately the university approved the committee's recommendation that the university retain its general education mathematics requirement and, in addition, require a statistics course with the understanding that it be "designed and taught like Contemporary Mathematics."

Another highlight of this phase of the assessment cycle was a series of structured visits to sections of Contemporary Mathematics. As a part of a program supported by a grant from the Division of Undergraduate Education of the National Science Foundation, in the late 1990s more than 100 faculty members, advisors, and administrators from VCU and other institutions visited Contemporary Mathematics classes. Prior to the visit, they learned about the course goals and the classroom activities planned for the day.

After the visit, they met with the instructors, and often students, to discuss their observations and reflections on the goals of the course. These discussions resulted in a variety of efforts to fine-tune the course.

The most recent highlight of this phase concerns the needs of students who enroll in College Algebra, particularly those majoring in business. In this case the initiative came from the Mathematics Department, not the partner discipline. In fall 2003, Mathematics Department Chair Andrew Lewis worked with VCU's Center for Teaching Excellence to set up a series of meetings between business and mathematics faculty. To facilitate discussions, all participants were given prepublication copies of Business and Management (Lamoureaux, 2004), a report on the recommendations of 37 faculty members convened for a weekend conversation at the University of Arizona as a portion of the MAA's Curriculum Renewal Across the First Two Years (CRAFTY) Curriculum Foundations project. This report begins with the statement that "Mathematics departments can help business students by stressing problem solving using business applications, conceptual understanding, quantitative reasoning and communication skills. These aspects should not be sacrificed to breadth of coverage" (CRAFTY, 2005, p. 19). VCU's business faculty concurred with this statement and together with the mathematics faculty identified a number of topics included in "the breadth of coverage" of our college algebra course that were not used previously in the Business School curriculum. These Business School faculty members encouraged the Mathematics Department to develop a modeling-based course, leading to the sections offered since fall 2004.

Phase Two: Designing, Refining and Offering Courses

As the courses have been designed and refined based on the needs of students and measurements of what is happening, our major boundary condition has been that the courses will be taught by transient instructors. Almost all sections were taught by graduate teaching assistants, or part-time or full-time instructors, 47 of these by individuals teaching at VCU for the first time. Therefore, the courses need to be designed and offered with a clear understanding of who will be providing the instruction. In one sense, the nature of our instructional staff provides flexibility, making it possible to structure the courses in the manner we choose. When we recruit and hire graduate assistants and instructors we make sure they know about and are interested in teaching the courses that we have designed. On the other hand, the nature of the staff requires ongoing course and professional development. We will highlight three aspects of this development: team teaching, instructor resources, and regular meetings of instructional staff.

Team teaching has been important in both original course development and ongoing professional development. Over the years at least 20 sections of Contemporary Mathematics have been team taught, including the first two offerings (Haver & Hoof, 1996; Haver & Turbeville, 1995). Five of the modeling-based sections of College Algebra have also been team-taught. In all 25 of these offerings, both members of the teaching team attended all class sessions. When materials and approaches are developed and piloted in a team-teaching format, it is likely that they can be used by a variety of different instructors. Team teaching also is an important tool in faculty development.

In addition to the 20 sections of Contemporary Mathematics mentioned above, one or two large lecture recitation sections are offered each semester. All students and all instructors participate in the large lecture that is offered once a week. The students attend one of the recitation sections that meets twice weekly. Instructors of the recitation sections build on what takes place in the large class meeting, making use of the materials and approaches prescribed by the lead instructor. Virtually all of the individuals who have taught Contemporary Mathematics in the past twelve years had their first teaching experience in this course as recitation section leaders or in another team teaching setting. After this first semester they are encouraged to be innovative in trying their own approaches, but during this first semester they are given firm guidance and expectations.

A detailed *Instructor's Guide for Contemporary Mathematics* (Haver, Kustesky, & Lohr, 1998) has been developed for the course, providing suggestions on actively engaging students, grading writing assignments, coordinating group projects, and conducting poster sessions. In addition, a Web site using the commercial software Blackboard[2] is provided for instructor activities, assignments, and writing prompts for students. Activities correspond to sections of the text, and include skill and practice worksheets to help students review algebra and other computational skills needed in the course. These materials provide the primary means for adjusting course content and activities based on our measures of what is happening in the course. Materials were developed and tested in the modeling-based College Algebra course. During the first two semesters, materials were developed and used in one section, then refined before being used in other sections held later in the day or the following day. By fall 2005 a website containing these and other materials was developed under the leadership of course developer Yvette Stepanian.

A third highlight of this phase of the assessment cycle is regular planning meetings of course instructors. Pre-semester day-long retreats and weekly planning sessions take place for both Contemporary Mathematics and modeling-based College Algebra. Instructors teaching the courses for the first time are required to attend these sessions, and many other instructors also attend. Meetings focused on support for instructors and discussion about what is working in their sections and the formal measures of what is happening. Short- and long-term revisions to courses are then developed based on this information and these discussions.

Together, team teaching, development of materials, and regular meetings constitute a combined course development and refinement process and faculty development program.

Phase Three: Measuring What is Happening

While a number of formal and informal measures have been made during these 13 years, we will highlight three components of this phase that have been conducted over the last three years (2002–2005).

- An assessment of the quantitative reasoning skills of students who completed College Algebra and Contemporary Mathematics.
- A survey of the amount of time students in College Algebra and Contemporary Mathematics spend on preparing for and participating in course-related activities.
- A detailed analysis of modeling-based College Algebra in comparison to a traditional approach.

<u>Quantitative Reasoning</u>

In spring 2002, we began a project to determine the extent to which general education mathematics courses help students develop quantitative reasoning skills. We first developed a set of questions to assess quantitative literacy. The questions were piloted on final examinations in spring 2002. Based on the results of that process, questions were added and others were changed or deleted. The final set of 16 multiple-choice questions addressed the following topics:

- Unit analysis
- Interpretation of charts and graphs
- Proportional reasoning
- Counting principles
- General percents
- Percent increase or decrease
- Use of mathematical formulas
- Average
- Exponential growth

The multiple-choice format was chosen due to the nature of the pre-course/post-course design we planned to implement. The questions were randomly distributed to create four instruments each consisting of four questions. Beginning in summer 2002, the assessment instruments were incorporated into the multiple-choice mathematics placement test taken by all incoming freshmen and transfer students. The questions continued to be part of the placement test through fall 2004.

Beginning in fall 2002, the four assessment instruments were included as the last page of final examinations in general education mathematics courses. The instruments were distributed in each class so that 25% of the students answered the questions on one version. As an incentive to participate, students were given one point of extra credit toward their final examination grade for every question they answered correctly. From fall 2002 through spring 2005, 1,034 students took both the placement test and the final examination in Contemporary Mathematics. Also, 1,423 students took the placement test and completed College Algebra. These students provided the data for analysis.

The 16 questions were grouped according to the topics listed above. In several cases, data from a question were used in the evaluation of more than one topic. Students' responses to the questions on the placement test were used to establish a baseline percent of students beginning a general education mathematics course with an understanding of each topic. One factor of the placement test that may have affected the baseline percents should be noted. A placement level is determined by the number of correct responses minus one-fourth of the incorrect responses. The directions state that test takers may choose to not answer questions if they are uncertain about an appropriate response. Between 10% and 25% of students taking the placement test did not provide an answer to eleven of the questions. With one exception, the other questions had lower no-response rates. Counting principles was the topic most affected with 55% of students who had a question on this topic not providing an answer. A statistical analysis of the percent of no-response items found that both courses were affected equally by this issue.

The percent of placement test and final examination responses for Contemporary Mathematics appears on the left side of Table 1. With respect to unit analysis, 26.69% of the students who took the placement test answered the questions correctly while 35.78% of the students answered the same questions correctly on the final examination. A two-sample test of proportions was used to statistically evaluate the data for each topic. For all but one topic, the percent of students answering the questions correctly after completing Contemporary Mathematics was significantly larger ($p < .05$) than the percent of students answering the questions correctly on the placement test. For the interpretation of charts and graphs topic, the final examination percent correct was also larger than the placement test percent but the difference was not statistically significant.

The percents correct for students who took College Algebra (modeling-based and traditional) appear in the right side of Table 1. As with the previous results, a two-sample test of proportions was used. For seven quantitative literacy topics, the percent of students answering the questions correctly after completing College Algebra was significantly larger ($p < .05$) than the percent of students answering the questions correctly before they took the course. For the two remaining topics, the percent of students answering the questions related to charts and graphs and general percents correctly after

Table 1
Percent of Correct Responses by Quantitative Literacy Topic

Topic	Contemporary Math		College Algebra	
	Placement Test	Final Exam	Placement Test	Final Exam
Unit analysis	26.69	35.78*	31.34	40.06*
Interpret charts & graphs	38.60	42.38	44.25	47.28
Proportional reasoning	22.77	34.13*	32.97	37.11*
Counting principles	26.80	42.74*	25.84	40.06*
General percents	38.97	48.32*	44.80	49.62
Percent increase/decrease	18.84	29.63*	18.73	31.99*
Use of math formulas	34.12	46.86*	37.66	52.60*
Average	39.83	59.62*	45.57	65.56*
Exponential Growth	19.62	38.52*	22.71	37.39*

* Significantly larger percent, $p < .05$

completing College Algebra was statistically similar to the baseline percent. This study provided us with statistical evidence that our lower level mathematics courses are helping to improve the quantitative reasoning skills of the students who take them. Further details and results can be found in other publications (Ellington, 2006; Ellington & Haver, 2006).

Time Spent on Class

To learn more about the study habits of our students, a multiple-choice item was added to final examinations for Contemporary Mathematics and College Algebra in spring 2003. The item was:

Please estimate, on the average, the total time you spend on this course. Include time in class, time taking tests, quizzes, and completing other projects or assignments.

a. Three hours or less each week
b. 3–5 hours each week
c. 5–7 hours each week
d. 7–10 hours each week
e. 10 or more hours each week.

As described earlier, the courses being compared were quite different in style and format. Most sections of Contemporary Mathematics were small, and students were engaged in group activities on a regular basis. In spring 2003, College Algebra followed the traditional approach outlined above with one exception. Due to budget constraints, lectures took place in classes of approximately 200 students. The percent of students selecting each response (see Table 2) are based on answers from 353 Contemporary Mathematics students and 402 College Algebra students who took the final examination in their respective courses. With respect to examination participation, there is a significant difference between these two courses. Over 24% of the students who began College Algebra withdrew, and many others did not take the final examination. Only 14.6% of students withdrew from Contemporary Mathematics, and of those who did not withdraw, almost all took the final examination.

Table 2
Percent of Student Responses to the Time Spent on Class Question

Response	Contemporary Math	College Algebra
3 hours or less	13.60	19.40*
3 – 5 hours	44.48*	33.83
5 – 7 hours	35.41*	26.12
7 – 10 hours	5.38	17.16*
10 hours or more	1.13	3.48

* Significantly larger percent, $p < .05$

Using a two-sample test of proportions, percents of students selecting each category were statistically compared. While each of these courses is worth three credits, they met for different amounts of time each week. Students in Contemporary Mathematics met for 150 minutes a week while students in College Algebra met for 150 minutes in large lecture and 50 minutes in the computer laboratory each week. As a result, students selecting the first response (3 hours or less) were admitting that they did not do much more than attend class. In fact, for College Algebra, students were stating that they did not attend all classes. The percent of students spending 3 hours or less on the study of College Algebra was larger ($p < .05$) than the percent of students spending the same amount of time on Contemporary Mathematics.

For Contemporary Mathematics, 80% of students stated that they spent between 3 and 7 hours engaged in course-related activities, while 60% of students in College Algebra spent a similar amount of time on that course. The percent of students spending between 7 and 10 hours on Contemporary Mathematics was significantly smaller ($p < .05$) than the corresponding percent of students in College Algebra. The data gathered from this question provided us with evidence that students taking College Algebra spent less time on the course than their Contemporary Mathematics counterparts. This and course withdrawal rates were two factors in our decision to make changes to College Algebra, including the development of a modeling-based version of the course.

Modeling-Based versus Traditional College Algebra

Our evaluation of College Algebra is the most detailed aspect of this phase of the assessment cycle. Five items were evaluated:

1. Grades in both forms of College Algebra;
2. Student performance on questions that appeared on the final examination;
3. Students' attitudes toward mathematics after completing the course;
4. Discussions during focus groups conducted with students at the end of the semester; and
5. Grades in courses completed one semester after passing College Algebra.

1. Course grades

During the 2004-2005 school year 466 students enrolled in modeling-based sections of College Algebra and 1,373 students were enrolled in traditional sections. The modeling sections were offered as described above in the section on Situation in 2005-2006, whereas the traditional sections with the exception of the laboratories were devoted entirely to the computer assignments. The quizzes and student activities were added to the course in fall 2005. The grades earned by these students were compared to the grades of the 2,682 students enrolled in large lecture sections during the previous three semesters (see Table 3). The ABC rate for students in traditional sections, limited to 35 students, was significantly higher than the corresponding rate for students enrolled in sections with class sizes of approximately 200 students. The ABC rate nearly doubled for the modeling-based sections with 67.60% of all students enrolled passing the course.

Interesting values embedded in these percents are the course withdrawal rates. When College Algebra was being taught in the large lecture format, 24.12% of students withdrew from the course. For the traditional

Table 3
Percent of Students Successfully Completing College Algebra, Spring 2003 – Spring 2005

Grades	Modeling	Traditional	Large Lecture
ABC	67.60	49.02	36.13
DFW	32.40	50.98	63.87

sections the withdrawal rate was 19.52%, while the rate was 8.15% for the modeling-based sections. The major difference between the large lecture sections and the traditional sections is class size; most other characteristics are the same. Therefore, the decrease can be attributed to smaller classes. The significantly lower withdrawal rate for the modeling-based sections is the result of all educational components including, but not limited to, the emphasis on mathematical models and daily use of group activities.

2. Common final examination questions

To gain a deeper understanding of how students performed, we designed a set of final examination questions to appear on both the modeling-based examination and traditional examination. In fall 2004,the questions were designed by one of the authors who was also an instructor of a modeling-based section. A total of 10 questions (7 skill-based questions and 3 application questions) were written with input from instructors of both College Algebra formats. The skills covered by the questions were taught in both types of College Algebra. The application questions were written in a manner similar to questions that appear in traditional textbooks.

The examination questions from all eight modeling-based sections (251 students) were evaluated. Eleven randomly selected traditional sections (285 students) were also part of the analysis. In order to eliminate grader bias, the questions were photocopied before instructors graded their examinations. The clean copies were graded by a different person who used the same method of partial credit for each test.

One modeling-based instructor changed one of the application questions on his examination; therefore, the data for his class was not included in the statistics presented for the application questions or for all questions (see Table 4). A two-sample *t-test* was used to statistically analyze the data. In all three categories (skills, application, all questions), the mean for the modeling-based sections was significantly larger ($p < .001$) than the mean scores for the traditional sections.

In spring 2005, a similar analysis was conducted with a different set of questions. The traditional sections received a concept review before each test. The modeling-based sections did not receive the same review before

Table 4
Student Scores on College Algebra Exam Questions – Fall 2004

	Modeling		Traditional	
	Mean	Std. Dev.	Mean	Std. Dev.
Skills Questions	67.05	10.58	60.59	9.10
Application Questions	74.29	7.64	68.49	7.47
All Questions	69.68	16.19	63.38	14.27

their tests, but they were given one along with students in the traditional sections before the final examination. The concept review questions were used to select questions for the common portion of the final examination. A subset of the questions was distributed to all college algebra (both types) instructors, who eliminated questions they did not want to use. At the end of several rounds of elimination nine skill questions and four application questions remained. These questions comprised the common final examination questions. The numbers in the problems were changed so that they were not exact matches of the questions in the concept review. As in the previous round of analysis, photocopies were made of the questions before instructors graded their examinations. A team of three graders was used to grade the examinations. To ensure that the same method of partial credit was used, the same person graded all responses to one question.

Table 5 contains the means and standard deviations of the examination questions for the three categories. These statistics are based on the grades of 141 students who took the final examination after completing a modeling-based section and 218 students in traditional sections. Based on two sample *t-tests* of each category, the results were different than those presented for fall 2004. With the questions taken from the concept review, students in the traditional sections performed better ($p < .01$) than the students in the modeling-based sections across all three categories.

Table 5
Student Scores on College Algebra Exam Questions – Spring 2005

	Modeling		Traditional	
	Mean	Std. Dev.	Mean	Std. Dev.
Skills Questions	69.30	18.30	76.50	17.30
Application Questions	48.40	27.80	54.20	26.80
All Questions	63.20	18.80	70.00	17.20

Grades for the common examination questions were determined by taking the number of points earned on the questions and dividing by the total number of points given to the set of 13 questions. A traditional grading scale (90–100 is an A, 80–89 is a B, etc.) was used to assign letter grades to the scores. Based on a two-sample test of proportions for the skills category and the all questions category, the percent of students in traditional sections receiving an A, B, or C on the common examination questions was significantly larger ($p < .01$) than the corresponding percent of students in modeling-based sections (see Table 6). For the applications category, the ABC rate for students in both college algebra formats was statistically similar.

Table 6
Percent of Letter Grades on Final Examination Questions – Spring 2005

	Modeling		Traditional	
	ABC	DF	ABC	DF
Skills Questions	54.61	45.39	70.18	29.82
Application Questions	26.95	73.05	33.03	66.97
All Questions	42.55	57.45	56.88	43.12

The questions used in the fall 2004 final examination analysis were different than the questions used in spring 2005. Therefore, we were not able to make meaningful comparisons between the two sets of data other than the fact that the modeling-based sections performed better on one assessment instrument and the traditional sections performed better on the other. We plan to collect and analyze data gathered in future semesters. Further details on this study can be found in Ellington (2005a).

3. Attitude toward mathematics

Both semesters, students' attitudes toward mathematics were evaluated using the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976). The scales used in this assessment project were confidence in learning mathematics, usefulness of mathematics, mathematics anxiety, and effectance motivation in mathematics (i.e., the level of motivation a person has to do mathematics). Six positively worded statements and six negatively worded statements for each scale were randomly distributed on the assessment instrument. Students used a Likert scale with five options (*strongly agree, agree, undecided, disagree,* and *strongly disagree*) to respond to each statement. By assigning a numerical value to each of the five options, students received a score of 12 through 60 for each construct. A higher score represents a more positive attitude. For mathematics anxiety, a higher score represents lower anxiety. The split-half reliability for each scale used is 0.87 or larger (Fennema & Sherman, 1976).

The assessment instrument was administered the first and last week of class. The mean scores for each scale are based on data from 187 students in ten modeling-based sections and 131 students in nine traditional sections (see Table 7). A student's scores were included if he completed the pre-course and post-course assessment instruments.

Across all scales and both college algebra methods, the post-course mean scores were not extremely different than the pre-course values.

Table 7
Pre-Course/Post-Course Means for Fennema-Sherman Attitude Scales

Fennema-Sherman Attitude Scale	Modeling		Traditional	
	Pre-Course	Post-Course	Pre-Course	Post-Course
Confidence in learning math	39.87	41.66**	41.67*	40.34
Usefulness of math	47.08	46.80	46.18	45.29
Ability to handle math anxiety	36.78	38.11**	38.88*	37.19
Effectance motivation in math	37.67	37.34	38.03*	36.52

** Significantly larger mean, $p < .01$, * significantly larger mean, $p < .05$

However, using a paired *t-test*, several results were statistically significant. For two scales (confidence in learning mathematics and mathematics anxiety) the mean post-course score was significantly larger ($p < .01$) than the mean pre-course score for students who completed modeling-based sections. Those students had more confidence in learning mathematics and less mathematics anxiety after completing the course than they did when the semester began. The pre-course/post-course means were not significantly different for the usefulness of mathematics and effectance motivation scales.

The results for data from students who completed traditional sections were quite different. For each scale, the pre-course mean was larger than the post-course mean. For three scales the results were statistically significant. At the 5% level of significance, the pre-course confidence level and effectance motivation level of students who completed a traditional section were higher than their post-course levels. Similarly, with respect to mathematics anxiety, students in traditional sections started the course with lower levels of mathematics anxiety than they had at the end of the course.

The results reveal that students in the modeling-based sections had an increase in their confidence in learning mathematics and a decrease in mathematics anxiety over the semester. Students in the traditional sections had a decrease in their confidence in learning mathematics, an increase in their mathematics anxiety, and a decrease in their level of motivation to do mathematics over the same time period. Therefore, it appears that the modeling-based approach did have a significant positive effect on students' attitudes toward mathematics.

4. Focus group discussions

Students were asked about their experiences during focus group interviews conducted at the end of the semester. In fall 2004, four focus groups were conducted each with 8 students from modeling-based sections. To incorporate the views of students in traditional sections, in spring 2005 one focus group consisting of 8 students in modeling-based sections and a second focus group consisting of 8 students in traditional sections were conducted. A combined focus group was also assembled with four students from modeling-based sections and one student from a traditional section.

Each focus group was 50 minutes in duration and was conducted with unbiased individuals skilled in conducting interviews. The questions used were designed by the interviewers with input from instructors. The discussions revolved around student experiences in their current course compared with their experiences in other mathematics courses; their views on assignments, especially those requiring group work; attendance policies; and suggestions for course improvements. Students in the modeling-based sections were also asked whether the instructors helped students reach the overall goal of the course—to think and reason mathematically by providing opportunities to work with data and develop models.

In the fall 2004 focus groups, students expressed that the modeling-based approach did not fit their perceptions of typical mathematics instruction —first learning mathematical skills and content and then solving problems and applications. This was the Mathematics Department's first attempt at a college algebra course with a focus on problem solving, and students clearly noticed the change. They expressed satisfaction with their experiences in the modeling-based sections as compared to their prior experiences or the experiences of their peers in large lecture courses. Over both semesters, students in modeling-based sections felt that they benefited from group discussions that allowed them to be more actively involved in class and gave them a better understanding of the concepts being covered. In contrast, students from traditional sections placed little value on group discussions. They perceived their success was based on their ability to complete the computer-based homework assignments and to do well on the tests, both of which are individual activities. Another interesting comparison between modeling-based and traditional experiences was course attendance. Students in modeling-based sections felt that attending class was important, especially with the emphasis on group activities. On the other hand, since homework is computer-based, students in traditional sections did not feel regular attendance was necessary.

While the traditional course was designed to improve the algebra skills of students, the modeling-based course was designed with a very different goal in mind. The underlying significance of all activities is that students work towards being able to think and reason mathematically. When asked during the focus groups if this goal was met, many students felt that it was. Many expressed that they were better problem solvers as a result of taking the course. Further information on the attitude assessment and the focus group discussions is available (Ellington, 2005b).

5. Grades in subsequent courses

College Algebra is a prerequisite for a skill-oriented precalculus course and a mathematical applications course for business majors. In spring 2005, we analyzed the grades of students in these two courses. A student's grade was included in the evaluation if he or she had passed College Algebra in fall 2004 or had been admitted into Precalculus or the business mathematics course based on the placement test or transfer credit from another institution. Table 8 contains the ABC rates for students who met one of these conditions.

Table 8
Percent of Students Passing a Subsequent Course in Spring 2005

Grades	Modeling (N = 167)	Traditional (N = 399)	Placement or Transfer (N = 294)
ABC	63.47	70.18	44.22
DFW	36.53	29.82	55.78

Based on a two-sample test of proportions, the percent of students who received an A, B, or C in a subsequent course after completing a modeling-based section the previous semester was statistically similar ($p > .05$) to the percent of students who received a similar grade in a subsequent course after completing a traditional section. However, both percents were significantly larger ($p < .001$) than the percent for students placing into Precalculus or business mathematics through other means. When the courses were considered individually, students from modeling-based sections had a higher ABC rate in business mathematics than their counterparts from traditional sections. However, the results were not statistically significant. With respect to Precalculus, the students from traditional sections had a significantly higher ABC rate ($p < .01$) than students from the modeling-based sections.

Table 9 contains data representing the success of students who took college algebra in fall 2004 and a subsequent course in spring 2005. It is noteworthy that 37.3% of students in modeling-based sections successfully completed the course and a course for which College Algebra is a prerequisite. Of those who enrolled in traditional sections, 28.3% completed the course and the subsequent course. Based on a two sample test of proportions, the percent of students in modeling-based sections who completed a subsequent course was significantly larger ($p < .01$) than the corresponding percent for students in traditional College Algebra sections. More details of this grade analysis can be found in Ellington (2005a).

Table 9
Fall 2004 College Algebra Students Who Passed a Subsequent Course in Spring 2005

	Number enrolled in College Algebra – Fall 2004	Percent who completed Precalculus or Business Mathematics – Spring 2005
Modeling Sections	284	37.3%
Traditional Sections	989	28.3%

Phase Four: Using Information to Refine Goals and Courses

As described in phase two, Contemporary Mathematics has been regularly refined based on what we have learned. Nothing that we have learned has changed our thinking about the overall goals of the course; however, based on information gained in phase three, we believe that the course can more effectively improve our students' quantitative reasoning abilities. During the 2005-2006 school year we are planning an overhaul of the course, taking into account all that we have learned. We will consider the possibility of changing the textbook and, regardless of whether we do so, we will overhaul our course materials. In particular, the redesigned course will place more emphasis on those quantitative reasoning skills on which students have made the least progress. The college dean has been apprised of our plan and has allocated $10,000 to the project so we can involve our part-time faculty in the process.

Beginning in fall 2005, the traditional sections of College Algebra added a more stringent attendance policy, weekly quizzes, and weekly exploratory activities. This change was made because it was believed that these features contributed to the lower withdrawal rates and higher success rates in the modeling-based sections. In the modeling-based sections, questions focusing exclusively on skills will be added to testing throughout the semester. Last semester, skills were only embedded in application-based questions. This change is in response to student performance on the common portion of the final examination and in the subsequent skill-based Precalculus course. More broadly, during our current stage in the assessment cycle, the department and faculty from the Business School will use the assessment data to consider the goals and direction of College Algebra. Possible outcomes include: continuing to offer two versions of the course with students having the option of which version to take, discontinuing either the traditional or the modeling-based approach, or developing a new course with features of both approaches. Of course, the decision will be made by individuals with their own educational and philosophical beliefs, but it will be informed by what we have learned.

Conclusion

As described in this chapter, the process of working through the assessment cycle numerous times has resulted in our current program. We simplified the development and refinement of the courses to provide an accurate picture of what occurred though many other factors influenced instruction in one way or another during this time. For example, the budget crisis that temporarily created the need for large sections was only briefly mentioned in this chapter. In addition, during this period of time VCU decided to offer only non-credit courses during the summer semesters and, therefore, require students who needed this work to take the course in the summer or at a community college. Currently, as faculty retire, VCU replaces tenured faculty positions with instructor positions. On the positive side, state requirements for high school graduation have been modified to require significantly more mathematics. So, these broader forces often “trump” even the most well-developed assessment program, and decisions are never made entirely on a rational basis or in a vacuum. Nevertheless, assessment activities have provided an important academic component to the decision making process. As long as the faculty members of our department take teaching, including the assessment process, seriously, our offerings at this level will continue to be modified in response to changes in our students, in the needs of their major disciplines, in the resources of our institution, and in the interests and strengths of our mathematics faculty.

Endnotes

1. Indeed, this was the situation during the entire period under consideration except during a statewide budget crisis of 2002-2003 and 2003-2004. During the crisis VCU made the decision, at the highest level, to hire virtually no part-time adjunct instructors in any discipline. So for these two years we (not very successfully) taught college algebra with full-time faculty in sections of approximately 200 students. When the budget crisis ended the department was able to resume staffing at previous levels.
2 Blackboard is a suite of computer software for instruction, communication, and assessment produced by Blackboard, Inc. of Washington, DC.

References

Committee on the Undergraduate Program in Mathematics (CUPM). (2004). *Undergraduate programs and courses in the mathematical sciences: CUPM curriculum guide 2004*. Washington, DC: Mathematical Association of America.

Curriculum Renewal Across the First Two Years (CRAFTY). (2005). *Curriculum foundations project: Voices of the partner disciplines*. Washington, DC: Mathematical Association of America.

Ellington, A. (2005a). A modeling-based college algebra course and its effect on student achievement. *PRIMUS*, *15*(3), 193-214.

Ellington, A. (2005b). A modeling-based approach to college algebra. *Academic Exchange Quarterly*, *9*(3), 131-135.

Ellington, A. (2006). An assessment of general education mathematics courses contribution to quantitative literacy at Virginia Commonwealth University. In L. A. Steen (Ed.), *Supporting assessment in undergraduate mathematics* (pp. 81-85). Washington, DC: Mathematical Association of America.

Ellington, A., & Haver, W. (2006). Contribution of a first year mathematics course to quantitative literacy. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 97-103). Washington, DC: Mathematical Association of America.

Fennema, E., & Sherman, J. (1976). Mathematics attitude scales: Instruments designed to measure attitudes toward the learning of mathematics by males and females. *Journal for Research in Mathematics Education*, *7*, 324-326.

Haver, W. & Hoof, K. (1996). Evaluating writing-intensive mathematics assignments. *PRIMUS, 6*, 193-208.

Haver, W., Kustesky, M., & Lohr, C. (1998). *Instructor's guide for Contemporary Mathematics*. Retrieved August 24, 2005, from www.math.vcu.edu/faculty/whaver/instructorsguide.html

Haver, W., & Turbeville, G. (1995). An appropriate culminating mathematics course. *AMATYC Review*, *16*, 45-50.

Lamoureux, C. (2004). Business and management. In S. Ganter & W. Barker (Eds.), *Curriculum foundations project: Voices of the partner disciplines* (pp. 19-26). Washington, D.C.: Mathematical Association of America.

Small, D. (2003). *Contemporary college algebra: Data, functions and modeling* (5th ed.), Boston, MA: McGraw Hill.

Tannenbaum, P. (2004). *Excursions in modern mathematics* (5th ed.) Upper Saddle River, NJ: Prentice Hall.

Wright, D. (2004). *Intermediate algebra* (5th ed.). Charleston, SC: Hawkes Publishing.

CHAPTER 7
TEACHING AND ASSESSING QUANTITATIVE LITERACY

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Introduction

Over the past two decades, teaching and assessment of K-16 mathematics have changed significantly. The National Council of Teachers of Mathematics (NCTM) led a national reform movement with standards for teaching and assessment of mathematics at the elementary and high school levels (NCTM, 1989, 2000), while colleagues in postsecondary education worked on reform of the teaching and assessment of traditional mathematics courses such as calculus (e.g., Moore and Smith, 1997). At the same time, external accreditation agencies and state governments demanded higher levels of accountability for higher education institutions. Gradually, the postsecondary conversation on mathematics reform began to include general education mathematics courses, the mathematics courses that serve as a prerequisite to courses in the majors or as an institutional graduation requirement. More recently, questions about the value and effectiveness of these required courses evolved into the rethinking of the way that mathematics itself is approached. A broader discussion of quantitative literacy (QL) has ensued. Much of the reform movement for traditional general education mathematics courses focused on more effective ways for students to acquire proficiency with increasingly complex mathematical processes and procedures. On the other hand, the QL reform movement has centered on effective ways to assist students to use basic arithmetic skills to interpret and reason with numbers and to develop the habits of mind to do so in everyday situations (Madison & Steen, 2003; Steen, 2001, 2004). Clearly, the movement toward QL has required re-thinking approaches to teaching and assessment and has needed to move beyond the teachers of mathematics.

Rethinking General Education Mathematics

In the early 1990s, Alverno College offered a freshman level course entitled Quantitative Strategies that satisfied the graduation mathematics requirement for the College but did not reflect the changing philosophy of the education community. A college-wide discussion of the general education mathematics requirement led to a consensus that quantitative literacy should be the focus of this course. The discussion considered current literature in quantitative literacy, mathematics, and teaching and learning, within the context of Alverno's educational philosophy and student demographics.

Many students enter Alverno College with a long history of failure in mathematics classes and a high level of mathematics anxiety. Alverno is a small, private college for women in Milwaukee, Wisconsin. Currently, the undergraduate degree-seeking enrollment is approximately 2000, with 36% students of color and 75% first generation college students. The average age of students is 27 years. Approximately 51% of incoming students are required to take at least one developmental level mathematics course before taking the general education mathematics course. Therefore, early research to inform curricular changes included literature on general mathematics reform (NCTM, 1989; Steen, 1990), critical mathematics education (Frankenstein, 1989; Frankenstein & Powell, 1989), math anxiety (Tobias, 1978), learning theories (Belenky, Clinchy, Goldberger, & Tarule, 1986; Gardner, 1983; Merriam & Caffarella, 1991; Perry, 1981), gender studies (American Association of University Women, 1991; Jacobs & Becker, 1991), multicultural considerations (Anderson, 1990; Knott, 1991), and learning disabilities (Nolting, 1992). In addition, Alverno College's curriculum is ability-based and follows an assessment model.

> Since the early 1970s, the Alverno College faculty have been developing and implementing ability-based undergraduate education, redefining education in terms of abilities needed for effectiveness in the worlds of work, family, and civic community. The distinctive feature of an ability-based approach is that we make explicit the expectation that students should be able to do something with what they know (Alverno College, n.d.).

The reviewed literature and student demographics supported a move to a QL-based approach to general education mathematics. Similarly, examining quantitative information by applying mathematical concepts within meaningful contexts matched Alverno's Student Assessment-as-Learning model. Under this model, assessment must be "a multidimensional process, integral to learning, that involves observing performances of an individual learner in action and judging them on the basis of public developmental criteria, with resulting feedback to that learner" (Alverno College Faculty, 1994, p. 4).

Instructional Services, the academic support department responsible for the developmental education program, pioneered the college-wide shift in mathematics curriculum from a skill-based approach to a quantitative literacy approach in 1992–1993. In the re-conceptualized developmental mathematics courses, students learned mathematical concepts while exploring quantitative information from government documents, newspaper and magazine articles, organization brochures, videos, and so forth. Quantitative questions were designed to allow students to demonstrate an understanding of mathematical concepts and to help them interpret the information. They discussed the strengths and weaknesses of the presentation of the information, how the quantitative data supported or failed to support the main point or perspective of the piece, what questions they could ask to gain a better understanding of the data, and what information they would need to gather to refute the conclusions made in the article. Originally, some course instructors were skeptical of this approach. Despite what the literature said, they feared that the context of the activities would take students “off track” and would slow down their skill development. Some were afraid that adding too much context, especially within an assessment, would distract students and would not allow them to demonstrate their skill ability.

To alleviate these fears, students were initially assessed using the traditional assessments that focused on demonstration of skill within limited, somewhat contrived applications. Student self assessments told instructors that the assessment style needed to match the instruction style. Students requested context-based assessments; they said that they would be better able to demonstrate their abilities under the new, contextual framework. In response to student comments and instructor observations, assessments were revised to be theme-based assessments that required students to use rich context to demonstrate mathematical concepts and procedures and to demonstrate the ability to think critically about the information itself. Interestingly, assessment results and student self assessment responses from these assessments indicated that unlike the context for classroom activities, the assessment context could not be so controversial that the students lost focus on their task. In class, students could explore issues of race, class, and reproduction, but for the assessments, they needed to focus on context that was rich, but not as emotionally charged. For example, while original theme-based assessments focused on issues such as violent crime, cancer, or abortion, later assessments asked students to explore issues such as farming in the state of Wisconsin to demonstrate ability to use fractions, proportions, and percents. They worked with information on crops, taxes, economic growth, and farm loss. After a series of quantitative questions based on the farm data, the students used evidence from the assessment to hypothesize reasons for farm loss in various counties. Students received feedback on both their procedural work and their interpretation of information.

Quantitative data on course success rates and qualitative evidence through faculty and student reflections were collected to evaluate the effectiveness of the curricular change. The success rate for students after the change in curricular framework and philosophy was greater than the success rate for students prior to the change. When comparing all degree-seeking students, success rates increased significantly from 68% to 80% ($p < 0.01$), and success rates for students of color increased significantly from 65% to 71% ($p < 0.01$). More importantly, from a quantitative literacy perspective, student qualitative journals and course evaluations showed a difference in attitude. A representative student wrote in her journal, "Yesterday I read an article for Social Science that dealt with a lot of numbers… I was very proud of myself because I questioned the numbers. In the back of my head, I heard [my instructor's] voice saying to always question the numbers to see what they really mean. It was very weird to sit and question a Social Science paper." Over time, the title of the developmental level mathematics course changed from "Math" to "Applying Mathematical Thinking" to indicate the true flavor of the course.[1] In early 1994, the general education mathematics course underwent a similar change from a skill-based approach to a QL framework. The course title changed to Mathematical Connections.

During the time that these changes occurred, the curriculum coordinator for these quantitative literacy courses worked with faculty across the college to inform them of the philosophical and curricular changes and to get their input. There were three primary goals of the resulting faculty workshops. The first goal was to explain and illustrate the difference between the previous skill-driven approach and the new quantitative literacy approach to the general education mathematics courses. Secondly, facilitators encouraged faculty advisors to avoid language such as "you just have to get through your quant course," and replace it with more positive comments about the value of the quantitative literacy ability regardless of major. Finally, the curriculum coordinator wanted to introduce context from various disciplines into the QL courses to help transference of mathematics concepts to discipline courses. Unfortunately, in follow-up conversations with instructors of courses served by the general education mathematics courses, faculty could not report increased transferability. Faculty reported students' lack of confidence, inclination, and recognition of mathematics concepts in their courses. Anecdotal evidence from employers of Alverno students indicated similar observations. Student comments on surveys confirmed this; one went as far as to write, "We don't do math at Alverno." Needless to say, Alverno faculty, staff, and administration knew that was not the case and were very concerned about the impression. Quantitative literacy needed to follow in the footsteps of writing across the curriculum and move from its ghetto-ized position to an institution-wide concern.

Defining Intermediate Level Quantitative Literacy

Prior to 1995, students were required to demonstrate beginning level quantitative literacy ability to fulfill their graduation requirement (see Appendix). The beginning level learning outcomes applied to the developmental and general education mathematics courses. Unlike other abilities at the college, quantitative literacy outcomes were defined only at the beginning level. In 1995, the QL curriculum coordinator convened an interdisciplinary workgroup to define learning outcomes for a new intermediate level quantitative literacy. By design, the intermediate learning outcomes would be demonstrated in discipline-based courses, not in additional general education mathematics courses that used a QL framework. The work of defining these outcomes moved very slowly. Initially, the workgroup tried to generate a list of tasks that students should be able to demonstrate. They had to remind themselves that the outcomes needed to hold for all students, regardless of major. A task that seemed important for management department majors may not be important to the art department majors. Eventually, the workgroup realized that a list of more mathematical concepts was not what was needed or wanted. What they really wanted was for students to be able to use the mathematical concepts, procedures, tools, and reasoning approaches that they had already learned to make meaning out of the complex ideas in the discipline. The workgroup submitted two key learning outcomes to the Curriculum Committee and the Educational Policies Committee to define QL at the intermediate level. These outcomes, with clarifying indicators, approved in late 1995, are as follows.

The student thinks critically about her own and others' use of quantitative information and language.

- Identifies quantitative relationships within a context.
- Shows awareness of the assumptions behind quantitative information.
- Shows awareness of the use/misuse of quantitative information.
- Recognizes the relationship between quantitative information and how it is presented to an intended audience.
- Uses basic quantitative abilities to accurately interpret quantitative information and evaluate arguments.

The student integrates quantitative abilities to effectively communicate information and respond to problems within a discipline related context.

- Shows evidence of a reflective, deliberate choice to use quantitative information in a discipline related context.
- Considers use of and, as appropriate, effectively uses calculators, and spreadsheet, graphing, or discipline specific software to communicate quantitative information.
- Organizes, appropriately uses, and clearly communicates quantitative information.
- Shows a refined sense of effective ways to present quantitative information for a specific audience.
- Evaluates her own use of quantitative information and argument and the implications of her choices.

In early 1996, demonstration of intermediate level quantitative literacy abilities was adopted as a graduation requirement beginning with students entering in the 1996–1997 academic year. Each discipline department was charged with the task of identifying at least two courses within its major sequence of general education or department courses where students could demonstrate the intermediate QL abilities. These courses needed to be in place by the spring semester of the 1997–1998 academic year.

In 1997, Alverno College received a National Science Foundation (NSF) Course and Curriculum Development, Institution–Wide Reform grant for Mathematical and Quantitative Reasoning Across the Curriculum (DUE – 9653689). The funds from the grant made it possible to have a member of Alverno College Office of Educational Research and Evaluation devote one-fourth time to program evaluation through surveys, focus groups, and syllabi audit. More significantly, funds made it possible to pay faculty for QL training, consulting with the Principal Investigators (PIs) of the grant, time to develop draft activities and assessments for identified courses, and follow-up feedback meetings with the PIs to discuss submitted drafts. This work occurred during summer 1997 and summer 1998. Then, the PIs compiled the activities and assessments to create a QL database that was accessible by all Alverno faculty. By reviewing the totality of materials, the PIs were able to pull out QL concept characteristics that became sorting criteria for the database. The characteristics included: graph, proportion, pattern or trend, functional relationship, algebraic strategy, geometric strategy, statistical measure, measurement, logic or argument, and number sense. A faculty member could search the database for examples of the characteristics in action in another discipline. For example, an instructor who wanted to strengthen her use of pattern and trend in her social science course could look at examples from nursing or management to find language and approaches that could be adapted to her discipline.

Examples of Intermediate Level Quantitative Literacy Assessments

The most exciting part of this project was the way faculty embraced the QL framework and adapted it to their disciplines. Below are three examples of QL assessments or activities from different disciplines using the seven-step assessment design model (Alverno, 1994):

1. Outcomes (QL specific)
2. General criteria (QL specific)
3. Prompt
4. Mode
5. Specific criteria (QL specific)
6. Directions
7. Feedback & self assessment

Example 1. **<u>Homeless Experience.</u>** This assessment was created by Catherine Knuteson for Nursing Theory and Practice in Health – Illness I, a course for 5th semester nursing students. It illustrates the use of a QL framework to analyze needs and services in the community. Students need to determine what type of quantitative and qualitative information is necessary to accurately assess the situation for mentally ill homeless people in the city of Milwaukee. Finally, they need to determine the best way to present this information to their peers.

1. QL outcomes:
   a. The student thinks critically about her own and others' use of quantitative information.
   b. The student integrates quantitative abilities to effectively communicate information and respond to problems within a discipline related context.

2. QL general criteria:
   a. Analyze the current political, social & economic issues related to the homeless and chronically mentally ill individuals in the community.
   b. Present current statistics and information regarding the homeless population in the Milwaukee area.

3. Prompt:
   It is estimated there are more than two million homeless people in the United States. Of these, approximately forty-five percent are mentally ill. It is projected these numbers will dramatically increase in the near future. Community health nurses are needed to care for this ever-increasing population. Nurses are steadily becoming more involved in outreach centers, shelters, and soup kitchens, where clients are assessed, counseled, and encouraged to accept treatment. As part of the mental health experience, you will be engaged in an "active" process exploring the issues surrounding the homeless and chronically mentally ill people in the community. You will also visit various community agencies that provide services for individuals and families in need of care and shelter.

4. Mode:
   As a group, you will present and discuss your findings on prevalence of homelessness and mental illness in the Milwaukee area, issues and laws governing mental health services, and information on the community agencies that you visit. Your audience will be other nursing students in the class.

5. Specific QL criteria:
   a. Identifies appropriate quantitative relationships with a context.
   b. Uses basic quantitative abilities to accurately interpret quantitative information.
   c. Analyzes patterns, predicting future trends and needs.
   d. Chooses appropriate representation of quantitative information to communicate information to the intended audience.

6. Directions:
   Participate in the half-day experience following the guidelines given to each group.
   a. During the walking tour of the assigned area, note observations regarding location, age, sex and appearance of homeless, available shelter from elements, etc.
   b. Visit the Milwaukee Public Library and collect current information on homelessness in Milwaukee, related laws and statutes governing mental health services, etc.
   c. Visit the assigned community agencies and collect information on their goals and purposes, funding, staff, services, clients, and projected trends and needs.
   d. Present findings to class. Include media using quantitative information, which clarifies or supports your presentation.

7. Feedback and self assessment:
   Complete criteria checklist (see specific criteria above), indicating your evaluation for each criterion listed. Provide specific evidence from your work to support your evaluation. Course instructor will use the criteria checklist to evaluate and comment on your work related to each criterion.

Example 2. <u>The Agricultural Revolution: What was the attraction of farming?</u> This is an activity created by James Roth for Western World Views, a course for 2nd and 3rd year students. It illustrates use of a QL framework to interpret records from the past in order to hypothesize reasons for a change in economic systems. The activity requires students to make assumptions regarding "missing data" based on their knowledge of history. This illustrates the difference between mathematics and QL, because the student can only make reasonable assumptions by using her interpolation skills *and* her historical knowledge.

1. QL outcomes:
   a. The student thinks critically about her own and others' use of quantitative information.
   b. The student integrates quantitative abilities to effectively communicate information and respond to problems within a discipline related context.

2. QL general criteria:
   a. To think critically about historians' use of quantitative information and language to determine patterns, trends and direction.
   b. To use quantitative abilities effectively to communicate evidence supporting your historical interpretations.

3. Prompt:

   Includes extensive context setting on the shift from hunting/gathering to agriculture.

   We still know that and when the transition to agriculture occurred, but we have not learned <u>why</u> hunters and gatherers would have wanted to make the change. Perhaps what we should be looking for is some way to compare features of the hunting and gathering versus agricultural life in order to decide whether the question even makes sense. If there were no advantage to the change, then we are asking the wrong question when we ask <u>why</u> they wanted to become agriculturalists. Instead, we will need to ask <u>what made it necessary</u> for them to become agriculturalists. Let's try to make use of the following ethnographic data about primitive groups of hunters and gatherers and of agriculturalists that have been studied by anthropologists during the 20^{th} century, relying on the assumption that, living in relative isolation from the modern world, they preserve aspects of the lives of their Stone Age ancestors. Create some comparisons between primitive agricultural and hunting and gathering societies to offer an answer to the question of whether or not hunters and gatherers would have wanted to convert to an agricultural way of life.

4. Mode:

   Group presentation with supporting quantitative evidence to explain what your comparisons signify.

5. Specific QL criteria:
   a. Identifies appropriate quantitative relationships with historical data.
   b. Uses basic quantitative abilities to accurately interpret quantitative information.
   c. Organizes, appropriately uses, and clearly communicates quantitative information.

6. Directions:
   a. Use provided data to create comparisons between primitive agricultural and hunting and gathering societies that you could offer as supporting evidence of what you think were the relative advantages/disadvantages of each type of economy.
   b. Do not attempt to link all of the categories of data. Create a couple of different graphics that clarify different aspects of the question. *Your purpose is not to show that you can manipulate all of the data; instead it is to use numerical data to help you think more clearly about the problem.*
   c. In some cases, you may need to make relative rather than absolute

numerical comparisons. You may also need to make assumptions about values of similar cultures.

d. Create graphic forms (tables or graphs) to illustrate your comparisons.

7. Feedback and self assessment:
Oral instructor and peer feedback on presentation. Class self assessment discussion regarding use of quantitative information to make inferences about an historical trend.

Example 3: <u>Analysis of "Harlem" & "Puzzled" by Langston Hughes</u>:
This example of an activity and outcomes was written by Marian Czarnik and Jonathon Little for American Literature II, a course for 3rd and 4th year English students. It illustrates the way a discipline department modified the language of the QL intermediate level statements to better service their students, without changing the intent of the outcomes. It requires the students to call upon geometric strategies to represent the structure of poems and arithmetic strategies to understand the setting of the poems.

1. QL outcomes:
   a. Student demonstrates the ability to observe and describe form and structure in works of literature.
   b. Student develops and conveys an understanding of historical, economic, and demographic information as it affects her experience in literature.

2. QL general criteria:
   a. Analyzes geometric structures in literature, including symmetry, proportion, and relationships between parts of a work of literature and the whole.
   b. Identifies, follows, and uses patterns of logic in argument, including inductive and deductive reasoning.
   c. Reads and analyzes demographic statistics and historical contexts as they affect her understanding of setting, plot, and culture in literature.
   d. Uses quantitative reasoning to analyze economic circumstances and systems as they are depicted in works of literature.

3. Prompt:
As a group, analyze the following poems using geometrical shapes in order to discern patterns of meaning in the poems "Harlem" and "Puzzled" by Langston Hughes. Use quantitative information to aid in creating an enhanced sense of historical and cultural context of Harlem in the 1940s and today.

4. Mode:
Visual representation of two poems.

Written narrative explanation of significance in comparing two poems. Written narrative explanation of connection between demographic and economic information and meaning of “Puzzled.”

5. QL specific criteria:
   a. Discerns appropriate patterns through the poem.
   b. Creates reasonable visual shapes to account for patterns of meaning with awareness of principles of symmetry, asymmetry, proportion, and relationship between parts of a work of literature and the whole.
   c. Accurately analyzes demographic statistics as they affect her understanding of the poems.
   d. Accurately uses quantitative reasoning to analyze economic circumstances and systems as they are depicted in works of literature.

6. Directions:
   For each poem,
   a. Identify meter and rhyme scheme.
   b. Identify the central image pattern or use of metaphor in the poem and chart its progress and variation.
   c. Create a non-verbal visual representation of the poem using regular shapes or a sequence of shapes. Account for the entire poem in your representation.
   d. Use the representations to compare the two poems.

   For “Harlem,”
   a. Create an argument about the poem’s meaning based on an inductive line of reasoning and the part to whole relationship. Show how the poem both adheres to logical form and departs from it.

   For “Puzzled,”
   a. Analyze economic information on Harlem in the 1940s as outlined in *The Harlem Renaissance (*Rampersad, 1995). Explain how this information sets context and relates to the meaning of the poem.
   b. Research statistics related to economic circumstances in Harlem today and draw comparisons. Would the narrator of the poem still be “puzzled?”

7. Feedback and self assessment:
   a. Discuss how the use of a geometric critical lens allowed you to see something you did not previously see, i.e. as a heuristic.
   b. Discuss use of creativity in applying mathematical shapes to poetry.
   c. Discuss how learning has been enhanced by application of quantitative literacy concepts.

Lessons Learned through Student Assessment

The three examples above illustrate the scope of quantitative literacy at Alverno College. They also illustrate some of the lessons learned during the first years of implementation and assessment of the intermediate level quantitative literacy outcomes.

The most common lesson learned from assessment results and student feedback was that working with the QL framework needed to be an ongoing, integral part of the course work. Some faculty initially scheduled a "QL day/week/unit," and the students viewed it as an add-on to meet a requirement instead of as a framework that was beneficial to learning the discipline. This perpetuated the idea that a student would get through mathematics and then would be finished with it. Over half of the faculty-written reflections indicated intent to revise their approach so as to infuse QL strategies throughout the term. Andrea Johnson, a professional communications instructor, wrote, "I recognize that I need to integrate rather than isolate my teaching of quantitative reasoning. At the end of the semester, I asked my students to evaluate the course assessments and learning experiences. Many students commented that the quantitative reasoning assessment seemed like an add-on instead of smoothly fitting into the progression of materials I was teaching. I will be working on a more integrative approach for the coming year." Although the NSF grant PIs discussed this during initial in-service and during individual consultations, the instructors did not understand the real need for integration until they reviewed student assessments and self assessments.

In addition to the need for integration of strategies, instructors discovered the need to explicitly indicate use of these strategies in their courses. Students did not always recognize that they were using their quantitative abilities when performing a specific task in a discipline course. Amy Shapiro, a philosophy instructor who often teaches for aesthetic responsiveness, one of Alverno's eight identified abilities, wrote, "For me [the role of QL in philosophy] is the reasoning dimension of making sense out of an argument. It comes so much closer to [the role of] aesthetic responsiveness than I had though… But, I had to show them how what they were doing was related to philosophy and to quantitative literacy." S. Marie Elizabeth Pink, a mathematics and computer studies instructor, made a similar comment. She wrote, "[Quantitative literacy as a] *way of thinking* is what I have been most struck by in this course… I need to make students much more aware of their thinking process by calling attention to it." During a gathering of teachers who included intermediate level quantitative literacy in their courses, some faculty found it interesting that a mathematics instructor would need to make QL thinking explicit in a mathematics or computer studies class. This led to an interesting discussion on the difference between traditional mathematics courses and quantitative literacy.[2]

Faculty also discovered the need to model appropriate use of these strategies. As the history instructor indicated in his assessment directions, “Your purpose is not to show that you can manipulate all of the data; instead it is to use numerical data to help you think more clearly about the problem.” Richard Butler, a business and management instructor, wrote, “[This work] made me realize the importance of working with students and to provide mental energy to continually make data analysis/presentation meaningful.” When instructors emphasized meaningful use of quantitative strategies in activities and assessments rather than tasks that were nothing more than arithmetic gymnastics, they reinforced the integral role of QL in their discipline. After working to infuse QL into one course, Kevin Casey, another history instructor, commented that he was including more activities that depend on QL abilities in his other courses. He wrote, “It’s important to teach students to understand how quantitative information informs historical narrative and interpretation.” As more instructors reinforce literacy strategies, both quantitative and language literacy, as appropriate in all of their courses, students will see “quantitative reasoning and quantitative strategies as tools rather than as an end themselves,” a goal Andrea Johnson, the professional communications instructor, identified for her courses.

A final lesson learned by instructors pointed to some necessary institutional level responses and applied more to the QL curriculum coordinator than to the discipline faculty themselves. Focus groups held at the end of the first few semesters of QL infusion raised instructor concerns. They acknowledged areas where they needed additional in-service professional development and support. These concerns fell into two areas —instructors’ insecurity with their own QL abilities, particularly mathematics skills, and instructors’ difficulty providing feedback to students. Over the last several years, the QL subcommittee has held voluntary in-service sessions on the mathematics concepts included in the beginning level QL courses. The discipline faculty were able to see what they could expect students to know when entering the class, and the faculty had the opportunity to brush up on their own mathematics. These brush-up sessions seemed to ease faculty concerns about teaching “math” in their discipline courses. The QL subcommittee also used the work of Edward Tufte (2001) as impetus for another session specifically focusing on literacy of graphs. Instructors worked with a criteria sheet for excellence in graphing that they could use with their students. This criteria sheet also provided language that the instructors could use when giving feedback to their students. The committee conducted follow-up sessions specifically to address the language of feedback. After a few semesters of struggling, instructors were ready to wrestle with feedback alongside other faculty who were experiencing a similar situation. One of the most prevalent comments regarding follow-up sessions was that talking with faculty teaching for QL in different disciplines was the most beneficial part of their in-service experience. They were able to talk with others about different uses of QL across the college and about the challenges of infusing QL in their courses. Because all of the members in the discussion had first-hand, recent experience with students, their suggestions for modification in assessments or activities were insightful and realistic. Furthermore, they requested ongoing opportunities to meet with other faculty who teach at intermediate levels. This experience circled back to the classroom again. As demonstrated in the three assessment examples above, instructors positioned students to work together and to receive feedback from their peers in order to strengthen their quantitative analysis and skills.

Looking Forward

The work to improve the teaching, learning, and assessment of quantitative literacy at the postsecondary level is an ongoing endeavor, not only at Alverno College, but also across the country. Each experience students and instructors have with the teaching, learning, and assessment process informs all involved. To improve assessment of QL at colleges and universities across the country, it is critical that professionals share these lessons with the broader education community. Alverno College faculty have worked to strengthen assessment of quantitative literacy by working with educators who visit the College, presenting ideas at conferences, conducting internal and external workshops, and serving as consultants and resource faculty for other institutions involved in developing the assessment of quantitative literacy across the curriculum. Professional organizations such as the Quantitative Literacy Special Interest Group of the Mathematical Association of America (http://www.maa.org/SIGMAA/SIGMAA.html), the National Numeracy Network (http://www.math.dartmouth.edu/~nnn/), and the Math Across the Curriculum and Quantitative Literacy Across the Curriculum projects through Washington Center for Improving Undergraduate Education at The Evergreen State College (http://www.evergreen.edu/washcenter/home.htm) are key links to resource materials and other educators engaged in assessing quantitative literacy. With the collective work of committed educators across the country, teaching and assessment of QL across the curriculum can become as accepted and beneficial to students as the teaching and assessment of writing across the curriculum.

Endnotes

1 See Alverno College Research and Evaluation Committee (1993) and Keeton, Mayo-Wells, Porosky, and Sheckley (1995), for further information on Alverno College's developmental mathematics program.

2 See Madison (2004) and Steen (2004, pp. 33-44) for more discussion on the difference between mathematics and QL.

References

Alverno College. (n.d.). *Ability-based curriculum*. Retrieved August 15, 2005, from http://www.alverno.edu/for_educators/student_as_learn.html

Alverno College Faculty. (1994). *Student assessment-as-learning at Alverno College* (3rd ed.). Milwaukee, WI: Alverno College.

American Association of University Women (1991). *Shortchanging girls, shortchanging America*. Washington, DC: Author.

Anderson, S.E. (1990). Worldmath curriculum: Fighting eurocentrism in mathematics. *Journal of Negro Education*, *59*(3), 348–359.

Belenky, M.F., Clinchy. B.M., Goldberger, N.R., & Tarule, J.M. (1986). *Women's ways of knowing: The development of self, voice, and mind*. New York, NY: Basic Books.

Moore, L., & Smith, D. (1997). *Project CALC: Calculus as a laboratory course*. Retrieved August 1, 2005, from http://www.math.duke.edu/education/proj_calc/

Frankenstein, M. (1989). *Relearning mathematics: A different third R – radical maths*. London, UK: Free Association Books.

Frankenstein, M., & Powell, A. (1989). Empowering non-traditional college students. *Science and Nature,* (*9*/*10*), 100-112.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York, NY: Basic Books.

Huggins, N. I. (1971). *Harlem ren*aissance. New York, NY: Oxford University Press.

Jacobs, J., & Becker, J. (1991). Women's ways of knowing: Implications for teaching mathematics. *WME Newsletter*, *13*(2), 7-8.

Knott, E. (1991). Working with culturally diverse learners. *Journal of Developmental Education*, *15*(2), 14–18.

Madison, B. (2004). Two mathematics: Ever the twain shall meet? *Peer Review, 6*(4), 9–12.

Madison, B., & Steen, L. (Eds.). (2003). *Quantitative literacy: Why numeracy matters for schools and colleges.* Princeton, NJ: National Council on Education and the Disciplines.

Merriam, S., & Caffarella, R. (1991). *Learning in adulthood: a comprehensive guide*. San Francisco, CA: Jossey-Bass.

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

National Council of Teachers of Mathematics (NTCM). (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Nolting, P. (1992). *Math and learning disabled students: A practical guide for accommodations*. Bradenton, FL: Academic Success Press.

Perry, W. (1981). Cognitive and ethical growth: The making of meaning. In A. Chickering (Ed.), *The modern American college* (pp. 76-116). San Francisco, CA: Jossey-Bass.

Rampersad, A. (Ed.). (1995). *The collected poems of Langston Hughes*. New York, NY: Knopf.

Steen, L. (1990). Mathematics for all Americans. In T. Cooney & C. Hirsch (Eds.), *Teaching and learning mathematics in the 1990s* (pp. 130-134). Reston, VA: National Council of Teachers of Mathematics.

Steen, L. (Ed.). (2001). *Mathematics and democracy*. Princeton, NJ: National Council on Education and the Disciplines.

Steen, L. (2004). *Achieving quantitative literacy: An urgent challenge for higher education*. Washington, DC: Mathematical Association of America.

Tobias, S. (1978). *Overcoming math anxiety.* Boston, MA: Houghton Mifflin Company.

Tufte, E. (2001). *The visual display of quantitative information* (2nd ed.). Cheshire, CT: Graphics Press.

Appendix
Alverno College Communication Ability Department
Quantitative Literacy Criteria

Beginning Levels:

Level 1: Uses arithmetic and algebraic methods to solve problems accurately.

- Shows awareness of specific strengths and weaknesses in her own quantitative performance.
- Performs and applies four basic operations using the Rational Number System.
- Solves ratio and percent problems related to everyday living.
- Solves and applies algebraic equations and inequalities.
- Uses quantitative skills in order to help recognize, create and solve problems related to everyday living.

Level 2: Interprets math models such as formulas, graphs and tables and draws reasonable inferences from them.

- Interprets, selects and constructs graphs using graphing software.
- Analyzes and visualizes geometric concepts.
- Applies measurement concepts.
- Expresses relationships as equations and/or graphs using spreadsheet software.
- Interprets and predicts data using basic probability concepts.
- Interprets, predicts and presents data using basic statistical concepts.

Intermediate Levels:

Level 3: Thinks critically about her own and others' use of quantitative information and language.

- Identifies quantitative relationships within a context.

- Shows awareness of the assumptions behind quantitative information.
- Shows awareness of the use/misuse of quantitative information.
- Recognizes the relationship between quantitative information and how it is presented to an intended audience.
- Uses basic quantitative abilities to accurately interpret quantitative information and evaluate arguments.

Level 4: Integrates quantitative abilities to effectively communicate information and respond to problems within a discipline related context.

- Shows evidence of a reflective, deliberate choice to use quantitative information in a discipline related context.
- Considers use of and, as appropriate, effectively uses calculators, and spreadsheet, graphing, or discipline specific software to communicate quantitative information.
- Organizes, appropriately uses, and clearly communicates quantitative information.
- Shows a refined sense of effective ways to present quantitative information for a specific audience.
- Evaluates her own use of quantitative information and argument and the implications of her choices.

CHAPTER 8
ASSESSMENT OF THE CORE MATHEMATICS PROGRAM

Alex Heidenberg
Mike Huber
Mike Phillips
The United States Military Academy

Introduction

In its simplest form, assessment is the process of gathering information about student learning. More important than collecting and analyzing this information is searching for meaning with respect to the student learning goals and acting on what is discovered. Lynn Steen (1999), writing in *Assessment Practices in Undergraduate Mathematics*, tries to uncover what we as teachers value and how we can check if our students will perform well.

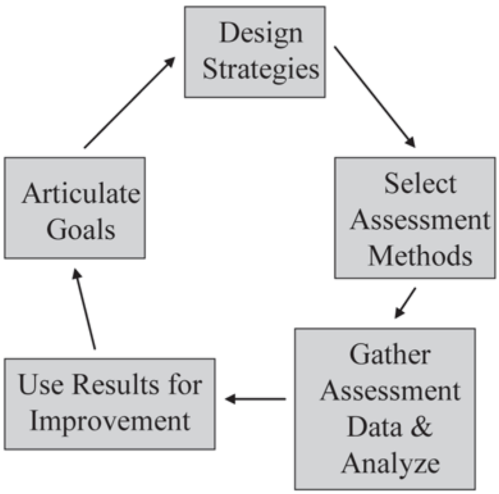
> Assessment serves many purposes. . . . At the summative stage — which may be at the end of a class period, or of a course, or of a special project — assessment seeks to record impact (both intended and unintended), to compare outcomes with goals, to rank students, and to stimulate action either to modify, extend, or replicate. (p. 2)

Summative stage assessment should indicate our success in developing our students into educated learners. Formal evaluation at the end of a course taking into account the summative assessment of learning can and should feed back into shaping the design of the course itself (Association of American Colleges & Universities (AAC&U), 2005). Steen reminds us that the assessment cycle begins with articulation of the goals. When the course ends and we have finished with our assessment tools (grading projects or final examinations, for example), we need to reflect back on our goals. Are the goals appropriate? Did we meet the goals of the course? What changes, if any, do we need to make to improve the educational experience?

One way to view assessment is as a never-ending cycle. There are five major parts to the assessment cycle, as outlined in *Assessment of Student Learning for Improving the Undergraduate Major in Mathematics* (CUPM, 1999). In relation to a course or academic program, they are:

1. Articulate the learning goals of the curriculum and a set of objectives that should lead to goal accomplishment.
2. Design strategies to accomplish objectives.
3. Select assessment methods designed to measure the progress of the students toward completing objectives and stated goals.

Figure 1: The Assessment Cycle



4. Gather assessment information and data. Analyze and interpret results.
5. Use the results to improve the course.

As depicted in Figure 1, the cycle of assessment continues without end. Step 5 from above—use the results—serves as the overarching goal of the assessment process: continual improvement. It is this aspect of assessment that exhibits its criticality in terms of course and curriculum development.

Vision and Learning Environment

It all starts with a vision. The assessment cycle begins with the articulation of learning goals for the curriculum. What are these goals and where do they come from? The core mathematics program at the United States Military Academy (USMA) has undergone a sustained evolution since 1985, when mathematical modeling was first introduced into the curriculum (Project Kaleidoscope, 2005). So, why continue to change? Continuous reflection at all levels provides assessment of our goals and allows for a culture of sustained improvement. In 1999, Dr. William Wulf, President of the National Academy of Engineering, speaking on the educational reform of engineering, gave our Department of Mathematical Sciences (department or DMS) cause to reflect on our curriculum. He concluded his remarks with an analogy to Wayne Gretzky, perhaps the greatest hockey player ever to play the game. Gretzky's foresight enabled him to skate to where the puck will be rather than to where the puck is. Dr. Wulf contended that engineering education is skating to where the puck once was. Dr. Wulf created the impetus for reflection: Were we guilty of skating to where the puck was? The department has long considered itself a leader in mathematics education reform; surely it could determine where the puck was going.

Continuing the analogy, we had to develop an answer to, "What is the puck?" The department's senior leadership conducted its annual off-site faculty development conference to reflect both on its learning goals and its curriculum. Determining where the puck was going suddenly took on secondary importance to identifying exactly what the puck was. What is mathematics and how should it be taught? How do we break away from the traditional ways in which mathematics has been taught? In the following, Lynn Steen (1992) shares with us one of the many problems that face mathematics reform.

> Mathematics shares with many disciplines a fundamental dichotomy of instructional purpose: mathematics as an object of study, and mathematics as a tool for application. These different perspectives yield two quite different paradigms … . The first … focuses on a core curriculum of basic theory that prepares students for graduate study in mathematics. The second … focuses on a variety of mathematical tools needed for a "life-long series of different jobs." (p. 189)

For our purposes, the puck has three parts. They are:

1. The needs of our students. Scientific, technological, engineering, and mathematical literacy in the general population will empower people to understand the impact of the policy issues which are principally created and justified in the language of mathematics and science.
2. The needs of society. Today's world is based, in large part, on information. Tomorrow's world will be influenced by advances in biology and other sciences.
3. The principles of our discipline. In textbooks, problems are manageable and have closed-form solutions based on theory and technique. In the real world, problems are messy, confusing, and often not accessible with current theory and techniques. Solutions take the form of trial and error, involve intuition, and require muddling through various solution techniques. Applied mathematics is the science and art of using theory, modeling, and approximation techniques to help explain the real world.

Articulating Goals in the Core Mathematics Program

Each year the DMS at the USMA conducts an assessment of its core mathematics program, which is the mathematics required of all students (cadets) at the USMA. The review and evaluation of the program design indicates what changes in the content and structure of our core curriculum are required to achieve program improvement.

According to DMS policies, core mathematics education at the USMA "includes both acquiring a body of knowledge and developing thought processes judged fundamental to a cadet's understanding of basic ideas in mathematics, science, and engineering. Equally important, this educational process in mathematics affords opportunities for cadets to progress in their development as life-long learners who are able to formulate intelligent questions and research answers independently and interactively" (DMS, 2005-2006, p.6). The expectation of a student who completes the core mathematics program at the USMA is that he or she will have developed a degree of proficiency in several modes of thought and habits of mind. Modeling and problem solving are critical points of focus. In addition to capturing abstractions in models, students should be able to reason deductively, inductively, algorithmically, and by analogy. We hope, each cadet will "possess a curious and experimental disposition, as well as the scholarship to formulate intelligent questions, to seek appropriate references, and to independently and interactively research answers" (DMS, 2005-2006, p. 6) to those questions. By studying and modeling transformations, each student should gain valuable insights and thus understand the role of applied mathematics.

The core mathematics program supports several of the USMA Academic Program goals outlined in the USMA operational concept for the Academic Program, *Educating Future Army Officers for a Changing World* (2002). The Academic Program is designed to accomplish the following: "Graduates anticipate and respond effectively to the uncertainties of a changing technological, social, political, and economic world" (USMA, 2002, p.16). There are 10 Academic Program goals, which support this overarching goal. The Office of the Dean at the USMA established an assessment steering committee to oversee goal teams for each of the 10 Academic Program goals. Each goal team focuses on assessing a single embedded indicator for its goal and meets throughout the semester to discuss how the indicators are being assessed. Of these 10 goals, five are particularly pertinent to the core mathematics program: (1) mathematics and science, (2) continued intellectual development, (3) communication, (4) creativity, and (5) technology. The primary contribution of the core mathematics program, however, is in support of the mathematics and science Academic Program goal to help students develop various modes of thought in a rigorous manner, to become capable problem solvers and develop scientific literacy to understand and deal with the issues of the military profession and society. The other four goals are addressed in a successive and progressive manner.

Students meet the mathematics and science goal when they demonstrate they can satisfy the following from the USMA list "What Graduates Can Do" (USMA, 2002, p. 22):

1. Understand the fundamental scientific principles that underlie military technology.
2. Understand the geophysical processes that govern the air-land-space environment.
3. Discern the scientific features or aspects of complex problems.
4. Construct mathematical models to facilitate the understanding and solution of problems.
5. Select and apply appropriate mathematical methods as well as algorithmic and other computational techniques in the course of solving problems.
6. Comprehend scientific literature appearing in the popular press.

The fourth and fifth items are particularly relevant to the core mathematics program. Any assessment agenda should address whether or not these items are being accomplished (are the goals being met?) and how we as educators know they are being accomplished. The DMS recognizes that one department does not have a monopoly on any particular goal; many academic departments own more than one piece of the "What Graduates Can Do" goal statements. The DMS designs a variety of appropriate student experiences allowing measurement of how the students perform and grow as self-directed learners, and designs a rubric to ensure that each core mathematics goal gathers feedback from multiple assessment techniques.

In order to develop students into competent and confident problem solvers, we establish goals (DMS, 2005-2006, p. 9) in the core mathematics courses that address the following:

- **Acquire a body of knowledge:** Acquiring a body of knowledge is the foundation of the core mathematics program. This body of knowledge includes the fundamental skills requisite to entry at the USMA as well as the incorporation of new skills fundamental to the understanding of calculus and statistics.

- **Apply technology:** Technology can change the way students learn. Along with increased visualization, computer power has opened up a new world of applications and solution techniques.

- **Communicate effectively:** Students learn mathematics only when they construct their own mathematical understanding. The successful problem solver must be able to clearly articulate his or her problem solving process to others.

- **Develop habits of mind:** Learning is an inherently inefficient process. Learning how to teach ones self is a skill that requires maturity, discipline, and perseverance. The core mathematics program seeks to improve each cadet's reasoning power by introducing multiple modes of thought. These modes of thought include deduction, induction, algorithms, approximation, implications, and others.

- **Build competent and confident problem solvers:** The ultimate goal of the core mathematics program is the development of each student into a competent and confident problem solver. Students need to apply mathematical reasoning and recognize relationships, similarities, and differences among mathematical concepts in order to solve problems.

Each of these goals supports the USMA Academic Program goals and the mathematics and science goals. Against each of these goals we make qualitative ratings as a *strength*, *mixed success*, or *weakness*. Numerical responses can be used when possible, but one should be careful not to discount reflection and subjective assessments. A sample assessment rubric matrix is shown in Figure 2.

Figure 2: Assessment Rubric Matrix

Goals/Assessment Tools	Fundamental Skills Exams	Class Work	Quizzes	Essays/ Writing	Exams	Portfolio	Student Feedback	Instructor Feedback	Interdisc-iplinary	Overall
Acquire a Body of Knowledge - Fundamental Skills - New Concepts										
Apply Technology - Enable Analysis - Right Tool for the Job - Multiple Representations										
Communicate Effectively - Written - Verbal - Reading										
Develop Habits of Mind - Deduction - Induction - Algorithms - Approximation - Implications										
Build Competent & Confident Problem Solvers - Confident and Curious - Values Self-Development - Appropriate Resources										

Designing Strategies

Once the goals for the core mathematics program are established, we turn to designing strategies to accomplish those goals and objectives. These strategies are then part of a learning model centered on student experiences. The USMA defines a learning model as the conditions in which its students learn. These conditions include the structure, process, and content of student experiences. A summary of each of these learning conditions follows.

Structure of the student experience. Core mathematics and science education at the USMA includes both the acquisition of a body of knowledge and the development of thought processes judged essential to a student's understanding of the fundamental ideas and principles in mathematics, science, technology, and engineering. This foundation allows graduates to progress in their development as life-long learners who formulate intelligent questions, research answers, reach logical conclusions, make informed decisions, and study other mathematical and science-based disciplines, such as engineering and economics.

<u>Process of student experiences:</u> The emphasis of the learning model is at the conceptual and fundamental skill levels: cadets internalize the unifying framework of mathematical concepts and learn to apply these concepts to problem solving. The mathematics and science Academic Program goal cites problem solving as a key element of the cadet experience. Specifically, it suggests that problem solving "promotes the internalization of concepts and enhances the development of sophisticated modes of thought" (USMA, 2002, p. 23).

<u>Content of student experiences</u>: Students who successfully complete the core mathematics program understand the underlying fundamental principles and thought processes: discrete and continuous, linear and nonlinear, and deterministic and stochastic mathematics. Students also develop a curious and experimental disposition, possess the ability to formulate intelligent questions, learn how to find and use appropriate information, and use technology to leverage their problem solving capabilities. The DMS at the USMA is considered a leader in the mathematics community in its innovative curriculum and teaching. Its core program (studied by all students) includes seven areas endorsed by curricular guidelines of the Mathematical Association of America (MAA): discrete mathematics, linear algebra, differential calculus, integral calculus, differential equations, multivariable calculus, and statistics (CUPM, 2004).

In addition to the learning model, using technology becomes a key ingredient in designing strategies. Technology has rendered obsolete many procedural skills that were important in the past, yet some procedural skills are so important and fundamental to learning both in our courses and in other disciplines that students should be capable of executing them without assistance from technology, such as computer algebra systems (*Mathematica* or *Maple*, for examples[1]) or programmable calculators. What are the skills that are truly fundamental? Lynn Steen (1990) shares with us one of the many challenges that we face.

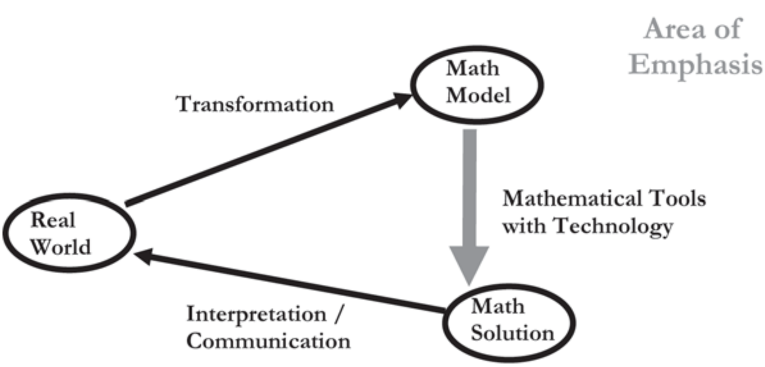
> The key issue for mathematics education is not whether to teach fundamentals but which fundamentals to teach and how to teach them. Changes in the practice of mathematics do alter the priorities among the many topics that are important for numeracy. Change in

> society, in technology, in schools – among others – will have a great impact on what will be possible in school mathematics in the next century.… To develop effective new mathematics curricula, one must attempt to foresee the mathematical needs of tomorrow's students. It is the present and future practices of mathematics—at work, in science, in research—that should shape education in mathematics. To prepare effective mathematics curricula for the future, we must look to patterns in the mathematics of today to project, as best we can, just what is and what is not truly fundamental. (p. 2-3)

Each of our core courses continues to identify these skills and use a non-technology assessment tool to evaluate the attainment of these skills. We cannot, however, work in a vacuum. We are responsible for preparing many of our students for the study of science and engineering. The identification of fundamental concepts must be done in conjunction with those departments that we service. After the strategies for accomplishing the goals and objectives are designed, we begin selecting those assessment methods to be incorporated into our program that will enable us to measure the progress of the students toward the completion of the stated goals.

Figure 3 shows the problem solving process depicted as a triangle of nodes and associated arcs. Traditional mathematics courses emphasize computational skills required to "solve" the problem.

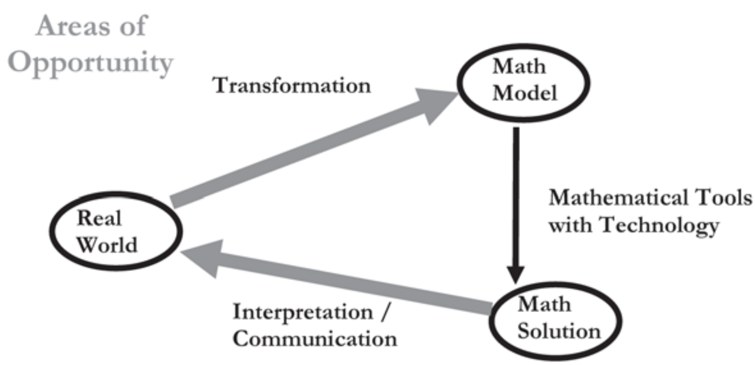
Figure 3
Typical Historical Approach to Mathematics Education



Technology has altered undergraduate mathematics and, more generally, information in our lives. Traditionally, most of the mathematics and information provided to students was selected for them and digested for them. Now, with electronic media, our students must learn how to acquire, select, evaluate, analyze, synthesize, and apply information.

Machines are better at computing; humans are better at reasoning. Personal computational skills are no longer the gateway for mathematics. Mathematics should focus on problem solving and the strengths and weaknesses of mathematics in the problem solving process. Figure 4 shows the adapted emphasis in the areas of transforming real world problems into mathematical models and interpreting the results of the mathematical solution back into the context of the original problem.

Figure 4
Adapted Problem Solving Approach to Mathematics Education



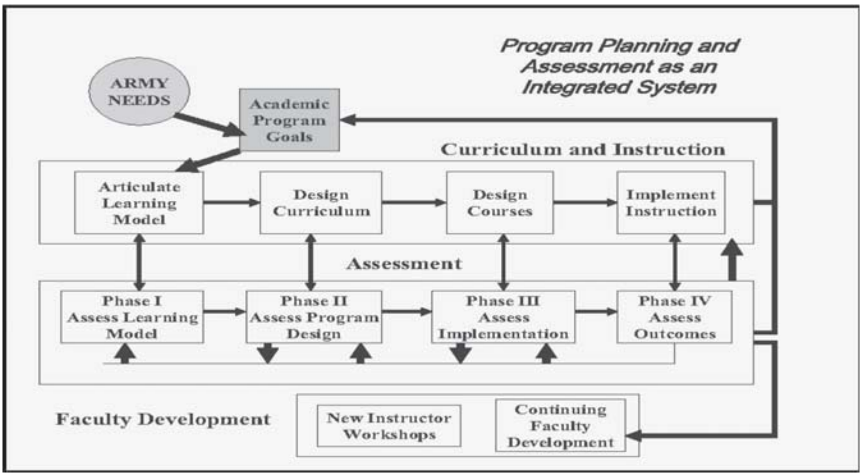
Traditionally, examinations make up the foundation of any assessment program. Each of our courses administers examinations that assess students both with and without the use of technology. Non-technology examinations focus on basic fundamental concepts associated with the core mathematics program. Non-technology examinations target basic skills deemed essential for students to continue with their mathematics, science, and engineering education. These examinations also provide opportunities to assess modeling and basic problem solving skills. Technology-based examinations present chances to assess student ability to use technology in mathematical computations. Additionally, they allow opportunities to assess advanced problem solving skills. Ideally, technology examinations offer opportunities to assess students' problem solving skills on an unrehearsed problem. Our objective is to assess student ability to make connections and recognize similarities and differences between problems they may have seen previously and new problems.

Our assessment program comprises of many different assessment tools that provide a comprehensive picture of a student's learning. Each different assessment provides a different perspective. If indeed, what you test is what you get, then if you never test skills without technology, students neglect these skills. If you use the same types of examinations with only the subject matter changed, students become proficient at taking that type of examination.

Selecting Assessment Methods

The design of experiences, their implementation, and the assessment of both the process and results are components of an inseparable system. Assessment outcomes impact curricular decisions at the course and program level. Similarly, the outcomes help reshape the learning environment that leads to new outcomes. Figure 5 shows the integration of program planning with assessment.

Figure 5
Program Planning and Assessment as an Integrated System



Assessment is a leadership responsibility. Baseball legend Yogi Berra (2002) is credited with providing words of wisdom, which can be applied effectively to any assessment initiative, when he said, “If you don’t know where you are going, you’ll probably end up someplace else” (p. 39). Leadership in a mathematics department, or at the university/college level, needs to present a vision for education to faculties, and assessment should be part of the vision. A vision of the goals is a way to make sure educators do not wind up someplace other than where they want to be. At the USMA, the department leadership communicates its vision often, to ensure we stay on track. As our department chair recently wrote in a Project Kaleidoscope

(2005) volume, “Continuous reflection at the individual, program, and department level is promoted, and thus creative adjustments within courses, programs, and the curriculum are not only encouraged, they are expected.” (p. 2)

The results of our reflections are changes to our curriculum that we believe “attempt to create a program that emphasizes creative problem solving—leveraging the power of human reasoning to formulate and validate, while using the power of technology to calculate” (Project Kaleidoscope, 2005, p. 2). Skating to where the puck will be means addressing each of the above parts in our vision for educating tomorrow’s leaders.

Most departments at the USMA rely on at least some portion of the core mathematics program to prepare cadets for studies in their departments. Additionally, the DMS has found that the study of mathematical principles and methods is almost always made easier by considering problems in applied settings with realistic scenarios. To facilitate success in both of these areas, the DMS has instituted a liaison program in which a tenured faculty member is designated as the liaison professor primarily responsible for coordination with a particular client department.

The major focus of this liaison program is to achieve a more integrated student experience by promoting coordination and collaboration between the DMS and the other science and engineering departments. The liaison professor fields questions, accepts suggestions, and works issues from the client department related to course material, procedures, timing, and any other matters of mutual interest. Additionally, he or she serves as the first point of contact for course directors in the DMS looking for examples and applications appropriate to their course and in need of referrals. This program provides a continuing source of information and input at the senior faculty level, ensuring that inter-departmental cooperation is accomplished across several courses in a consistent fashion.

Gathering Assessment Data and Analyzing the Results

We gather information on student learning in many ways, but most methods are integrated with curricular and institutional academic processes. The following illustrate ways that we gather data, make observations, and analyze the results.

Discrete Dynamical Systems

In 1990, our department changed its core curriculum to include a course in discrete dynamical systems. The goals for student learning at that time included:

A. Learn to use mathematics as a medium of communication that integrates numeric, graphic, and symbolic representations, structures ideas, and facilitates synthesis.

B. Develop the ability to think mathematically through the introduction of the fundamental thought process of discrete, continuous, and probabilistic mathematics.
C. Provide an orderly transition from the environment of a high school curriculum to the environment of an upper divisional college classroom.
D. Integrate computer technology throughout the four-semester curriculum.
E. Integrate mathematical modeling throughout the curriculum to access the rich application problems.

These goals remain the most important aspect of our first core mathematics course. In fact, advances in technology and its access in cadet classrooms make these goals even more important today; however, in our efforts to successfully implement a program that included discrete dynamical systems, we found that the program did not adequately meet some of its goals. For instance, the program did not provide a strong transition from high school to college; mathematical modeling was subordinated to the solution process of various types of discrete dynamical systems; and the program did not sufficiently integrate numeric, graphic, and symbolic mathematics. In addition, student attitude surveys historically indicated negative connotations associated with discrete dynamical systems. We concluded that the course title and content should refocus on its original intent: modeling and problem solving.

Entry-Level Skills

Weak entry-level, fundamental skills found in a small segment of our student body impede their learning in the basic sciences. A list of these skills is provided to every student accepted for enrollment at the USMA and identifies them as required entrance skills. Whatever proficiency these students have at entry, it is apparent that their skills rapidly decay.

Data Analysis

To produce graduates who effectively anticipate and respond to the uncertainties of a changing world, it is important to introduce data analysis as a theme across the entire core mathematics curriculum. However, it had been found only in our Probability and Statistics course, the fourth course in the core sequence.

Benchmarking

Discussions, presentations, and findings presented at the annual meetings of the Mathematical Association of America indicate that our teaching practices are in line with those of other universities whose students have access to laptop computer technology. We continue to benchmark our curriculum and teaching strategies with Rensselaer Polytechnic Institute, Duke University, Rose-Hulman Institute of Technology, Harvey Mudd College, the United States Air Force Academy, and Carroll College (Montana).

Course-End Reports

Integration of curricula and assessment is essential. It has been argued that assessment outcomes impact curricular decisions at the course and program level. The learning environment is continually reshaped based upon responses to new changes. Maintaining an organized system of tracking progress is an important part of continued improvement, and one mechanism for this at the USMA utilizes course-end reports. We find that the use of course-end reports is very important in assisting us to gather and analyze results.

The course-end report is a collection of informed analyses and discussions of the course, its goals, and whether the students achieved the course learning goals. It is more than a collection of assessment measures from each course; it is a thoughtful analysis of this information to gain insight into courses and our curriculum. Once the analysis is complete, course leadership should take appropriate action to improve the course, majors, and the curriculum. The cycle is endless: collect, analyze, act.

The course-end report is a compilation of the instructor's (or, if several instructors teach the same course, the course director's) assessment of the recent course. It serves as one of the primary means for the department to determine how we specifically address each of the program goals stated in the current core mathematics description (or institutional/department catalog): how the course addresses each of the goals, the assessment tools that provide evidence, and a summary of the results of these assessments. The report includes a summary of the initiatives implemented within the course and a discussion of suggested changes for the next cycle of the course.

At a minimum, the course-end report should have appendices containing the following:

1. Instructional memorandum. This is an administrative document outlining the purpose and goals of the course, comments on grading, assessment tools that will be used, and course philosophy.
2. Syllabus/course guide. This is an outline of topics to be covered during the course; it can be as detailed as necessary.
3. Copies of all course-wide examinations.
4. Copies of suggested solutions to course-wide examinations, with grading rubric and after-action review comments on each examination.
5. Copies of course-wide projects, with suggested solutions.
6. Copies of any student portfolio guidance for the course.
7. Other documents necessary to provide continuity for the new course leadership.
8. A reflective summary of the course director's comments and recommendations for the course in the future. This is perhaps the most

informative section of the course-end report. For example: Did the students value the textbook and was the textbook appropriate for the course goals? Did the midterm examinations assess what the instructor wanted students to understand? Is the use of technology appropriate for the course? How well did the students adapt to using technology in the classroom? Did the assessment tool match the objectives? This implementation question must be followed by an outcome question: How did the students perform with respect to the course goals? Perhaps an instructor tried a new style or collected homework during the semester. Did it work? What changes would make the course better?

Other items that can be included (but are not limited to): feedback from students (such as end-of-course surveys, exit interviews, etc.), and copies of technology tutorials used in the course (for example, include computer algebra system commands most often used in the course). These can be used to build a toolkit that the students may take with them from course to course. In years that the institution is undergoing accreditation, instructors will be required to keep sets of original student work (good, bad, and average). The course-end report then becomes a valuable reference in assisting for the preparation of an accreditation visit. The associations that accredit institutions “believe strongly in the value of assessing student learning” (AAC&U, 2005), so the course-end report is a valuable document to record that assessment. In addition, the items contained in a mathematics course-end report are useful when creating resources for engineering program and other accreditation reviews.

Some courses are taught by members of different departments. For example, an engineering mathematics course, offered by the DMS, could have a professor from the Department of Civil Engineering. A visiting professor’s feedback in the course-end report lends valuable insights into how well DMS provides appropriate support to a client department.

Using Results for Improvement

The title of our first course in the core mathematics program was changed from *Discrete Dynamical Systems and Introduction to Calculus* to *Mathematical Modeling and Introduction to Calculus*. The change provided a more accurate description of the course content and objectives and presented an opportunity to change student perception of the course.

The course’s main emphasis was placed on applied mathematics through modeling—using effective problem solving strategies and modeling theory to solve complex and often ill-defined problems. Problem solving strategies are now introduced to students in the first two weeks of the semester and remain a theme throughout the course. Elements of discrete dynamical systems remain a part of the course, but they are treated as one of many approaches to problem solving.

The course strengthened its role of providing an orderly transition from the high school curriculum to the environment of an upper division college classroom by stressing mathematical modeling and functional notation, while introducing data analysis and computer application programs that support scientific inquiry. The course exploits a variety of technological tools to develop numerical, graphical, and analytical solutions that enhance understanding.

All good assessments of learning involve a well thought out, well-conceived plan that involves multiple modes of assessment. Quizzes, graded homework, technical reports, and examinations have traditionally provided sample data regarding what our students are learning. Paramount in the assessment process is determining what concepts and skills we want our students to learn in our core program. It is understood that *what you test is what you get*; therefore, we have adapted our examinations to assess these desired concepts and skills. The assessment rubric matrix given earlier in Figure 2 became a useful tool in gathering assessment data.

As the world continues to change technologically, socially, politically, and economically, educational curricula must adapt to best prepare graduates to meet the ever growing demands as leaders and problem solvers. Undergraduate education is a unique, sterilized microcosm that reinforces the fundamental skills, technical skills, problem solving processes and critical thinking necessary for effective problem solving. Continued refinements in what we teach, how we teach, and what we assess creates the blueprint in focusing student learning to achieve our goals.

The assessment of technology-enhanced learning has thrust the mathematics community into unfamiliar territory. Textbooks are filled with sample problems that focus on computation and procedural skills and mathematicians are very comfortable and generally proficient at creating grade scales for assessments based on procedural skills. As mentioned earlier, technology has rendered many procedural skills obsolete. Each of our core courses continues to identify these skills and have a non-technology assessment tool to evaluate attainment of these skills.

Much of the focus of our curriculum is on process. Creating assessment tools for mathematical processes is much more difficult. This type of assessment is new to most mathematicians, and we continue to grow. Learning to ask questions correctly to determine the problem solving processes of our students is an art. We think much differently than our average student, and often see better ways of asking the question only after we see student responses.

Determining what a student was thinking is more difficult. It was easy to follow work down to the underlined answer and determine correctness or where the calculations were flawed. Most of the calculations are now done with *Excel* or *Mathematica*. (See Endnote 1.) Correct answers are generally explained and easy to evaluate. However, when a student struggles, it is difficult to determine the appropriate degree of proficiency or failure.

Time is critical in problem solving, and even more critical when assessing its process. We want to allow our students the opportunity to demonstrate their ability to make connections and analyze higher order problems, but we do not want our assessment to be too narrow and centered on one problem or scenario that could potentially cripple a student and not provide an adequate sample of their ability. We need to continue to assess using technology in the classroom thereby communicating to our students that mathematicians use technology in their modeling and computations. We use read-aheads and provide data sets ahead of time to eliminate some time issues; graded homework assignments are more prevalent assessment tools than in the past.

We continue to learn how today's students prepare for examinations that allow the use of technology. The computer provides a reference sheet measured in gigabytes. Many choose to scan in old assignments and try to pattern match during the examination. (Obviously, this is not efficient and results in less than favorable results. We continue to develop our students into mature learners.) Other issues arise when allowing students to use technology on an examination. Residue from the examination remains on the computer following an examination. This residue is transferable between students with the click of a mouse, so we have taken advantage of a common testing hour to minimize this problem.

We continue to learn how to best incorporate the latest technology in our assessments. Ongoing assessment has lead to an environment that is different both to our most senior faculty and our newest junior rotating faculty. Discussions of our assessment practices must continue to take place within all levels of faculty development.

The Assessment Cycle Continues

Assessment in the DMS at the USMA is a continual process. New initiatives are introduced into the core mathematics curriculum after careful development of goals and objectives, which ultimately relate back to what we feel our graduates should be able to accomplish. After the initiatives are introduced, the outline of the assessment process is followed, and careful reflection of the outcomes of assessment is made. This reflection is captured in a course-end report for each course and also used to improve the course or individual initiative. The introduction of technology into the curriculum has forced us to develop innovative teaching and assessment techniques. We are developing students into confident and competent problem solvers who can acquire a body of knowledge and develop thought processes judged fundamental to their understanding of basic ideas in mathematics, science, and engineering.

Endnotes

1. Mathematica and Maple are mathematical software systems. Mathematica is a product of Wolfram Research while Maple is a product of MapleSoft.

References

Association of American Colleges & Universities (AAC&U). (2005). *Greater expectations national panel report*. Retrieved June 1, 2005, from http://www.greaterexpectations.org/

Berra, Y. (2002). *What time is it? You mean now?* New York, NY: Simon & Schuster.

Committee on the Undergraduate Program in Mathematics (CUPM). (1999). Assessment of student learning for improving the undergraduate major in mathematics. In B. Gold, S. Z. Keith, & W. A. Marion (Eds.), *Assessment practices in undergraduate mathematics* (pp. 279-285). Washington, DC: Mathematical Association of America.

Committee on the Undergraduate Program in Mathematics (CUPM). (2004). *CUPM curriculum guide 2004*. Washington, DC: Mathematical Association of America.

Department of Mathematical Sciences (DMS), United States Military Academy (USMA). (Academic Year 2005–2006). Core Mathematics. West Point, NY: Author.

Project Kaleidoscope. (2005). Preparing 21st century leaders: A departmental responsibility. *Project Kaleidoscope Volume IV: What works, what matters, what lasts*. Retrieved June 21, 2006, from http://www.pkal.org/documents/Vol4Preparing 21stcenturyleaders.cfm

Steen, L. A. (1990). Pattern. In L. A. Steen (Ed.), *On the shoulders of giants: new approaches to numeracy* (pp. 1-10). Washington, DC: National Academy Press.

Steen, L.A. (ed.). (1992). *Heeding the call for change: Suggestions for curricular action.* Washington, D.C.: Mathematical Association of America.

Steen, L. A. (1999). Assessing assessment. In B. Gold, S. Z. Keith, & W. A. Marion (Eds.), *Assessment practices in undergraduate mathematics* (pp. 1-6). Washington, DC: Mathematical Association of America.

United States Military Academy (USMA). (2002). Educating future Army officers for a changing world: Operational concept for the Academic Program at the United States Military Academy. West Point, NY: Author.

CHAPTER 9
ASSESSING CORE COURSES: EFFECTS OF MULTI-SECTION COORDINATION

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Introduction

In the mid-1980s, many states passed laws requiring universities to provide annual reports concerning their assessment efforts (Olds, Moskal, & Miller, 2005). Universities were being asked to explicitly state their goals and demonstrate that their students were achieving these goals. Both regional and professional accreditation agencies shifted their focus from numerical summaries of university resources to outcomes based education. By the start of the current millennium, most regional and professional accreditation agencies were requiring direct evidence that students were achieving program specific goals.

Most mathematics departments entered the assessment arena grudgingly (Madison, 1991). Since there is no agency that accredits mathematics programs, mathematics departments often became involved in assessment because of their relationship with other accredited departments, such as engineering and computer science. The direct benefit of assessment to the mathematics department was often unclear, and the justification for implementing an assessment program was frequently based on federal, state, or university mandates.

The Mathematical Association of America (MAA) Committee on Undergraduate Programs in Mathematics (CUPM) Subcommittee on Assessment has responded to these concerns regarding assessment within mathematics departments. The subcommittee has argued that properly designed assessments can directly benefit instruction and learning in the department. Specifically, well designed assessments provide information that responds to the following questions (CUPM, 1995): 1) What should our students learn? 2) How well are they learning? and 3) What should we change so that future students will learn more and understand it better? Responding to these questions not only helps departments judge how successful they have been with respect to supporting student learning, but also how they can become more successful in the future. CUPM's Subcommittee on Assessment has provided further guidance to mathematics departments by proposing a five-phase assessment cycle (CUPM, 1995): 1) articulating goals and objectives, 2) developing strategies for reaching goals and objectives, 3) selecting instruments to evaluate the attainment of goals and objectives, 4) gathering, analyzing, and interpreting data to determine the extent to which goals and objectives have been reached, and 5) using the results of assessment for program improvement. When the final phase is reached, the assessment cycle begins again. This conceptualization of the assessment process is consistent with other literature on assessment (National Council of Teachers of Mathematics (NCTM), 1995; Steen, 1999).

Over the last several years, the assessment cycle as proposed by CUPM has been repeatedly tested and used by the mathematics community through the project, *Supporting Assessment in Undergraduate Mathematics* (SAUM), which is sponsored by the MAA with National Science Foundation support. This project offered a series of workshops that assisted mathematics faculty in developing and implementing departmental assessments. As part of this effort, a website is currently available that contains numerous examples of the applications of this model to mathematics departments across the nation (see http://www.maa.org/SAUM/index.html). The Mathematical and Computer Sciences Department (MCS) at the Colorado School of Mines (CSM) is one example of a mathematics program that participated in the SAUM workshops. As a result of these efforts, two case studies concerning MCS's assessment plan have already been published through SAUM (Moskal, 2003, 2005). These articles were designed to describe the department's overall assessment plan.

This chapter has a narrower focus than did these prior two papers, examining a single component of our assessment plan—coordinated courses. Coordinated courses in MCS occur in the core (*i.e.*, required courses) and are characterized by having multiple sections, taught by different instructors. A lead faculty member coordinates regular meetings at which participating instructors share instructional strategies and to create common assignments and/or examinations. This faculty member also ensures that the designated program objectives are assessed through common assignments and/or examinations. In MCS, there are five coordinated courses, Calculus for Engineers I (Cal I), Calculus for Engineers II (Cal II), Calculus for Engineers III (Cal III), Differential Equations (DEq), and Probability and Statistics for Engineers (Prob/Stat). This paper will examine the effectiveness of using coordinated courses as part of the assessment process.

Methodology

This section begins with a description of the student population at CSM and is followed by a description of the assessment instruments used. As in most studies of this type, multiple methods were selected to provide convincing evidence to support the interpretation of the results.

Student population. CSM is a public research institution in applied science and engineering. During the academic year 2005-2006, entering freshmen averaged 1250 on the SAT, 27 on the ACT, and 3.7 for their high school grade point average. The student body consisted of approximately 2950 undergraduates and 725 graduate students. Colorado residents comprised approximately 79% of the student population and foreign-born students approximately 9%. Females and minorities made up 23% and 14%, respectively.

Eight academic units—Chemical Engineering, Engineering, Engineering Physics, Geological Engineering, Geophysical Engineering, Metallurgical and Materials Engineering, Mining Engineering, and Petroleum Engineering — have programs that are accredited by the Accreditation Board for Engineering and Technology (ABET). Approximately 69% of CSM undergraduates complete degrees in these departments. All undergraduate majors in the school have a minimum of 12 required credit hours in courses that are offered through MCS. In other words, at a minimum, every CSM student completes Cal I, II and III either with credit from high school or college. Additionally, approximately 12% of undergraduate students declare majors in MCS.

Differences in Coordination

As was previously discussed, in order to ensure consistency across courses within the first two years of instruction, MCS has established five coordinated courses: Cal I, Cal II, Cal III, DEq and Prob/Stat. Although the theory behind coordination is to establish consistency across the course and the instruction received, there are differences in how coordination is implemented based on instructor and coordinator preferences. These differences for the Spring 2005 are summarized in Table 1.

Table 1
Summary of Coordinated Course Differences for Spring 2005

Course	Frequency of team meetings	Method for Developing Test	Method for Scoring Test	Feedback Acquired from Instructors
Cal I	1 per week	Team Development	Team Scored	Extensive
Cal II	1 per week	Team Development	Team Scored	Extensive
Cal III	1 per week	Team Development	Team Scored	Extensive
DEq	Never	Team Development	Team Scored	Limited
Prob/Stat	2 per semester	Coordinator Development	Coordinator Scored	Very Limited

As the data in this table indicate, the instructors and the coordinators for the calculus sequence met approximately once per week, developed tests collaboratively, created a common scoring rubric and scored tests collaboratively. In DEq, instructors did not have team meetings during the semester, but rather used e-mail correspondence to team develop tests and complete team scoring of tests. The Prob/Stat instructors met twice during the semester; both times were immediately prior to the test and lasted less than ten minutes each. The coordinator for Prob/Stat developed and scored all tests and sought only limited feedback from the course instructors.

Based on these descriptions, the final column of Table 1 summarizes the amount of feedback that the coordinator received from course instructors: *extensive*, *limited* and *very limited*. Extensive refers to a team process that included frequent meetings, team development of tests and team scoring of tests. Limited refers to a team process that included e-mail correspondence, team development of tests, and team scoring of tests. Very limited refers to a team process in which the coordinator made the majority of decisions with little feedback from the other instructors.

Assessment Instruments

In each of the coordinated courses, grading across sections is completed in a consistent manner. Either a single instructor scores a subset of problems for all students across sections (Cal I, II, and II and DEq) or the course coordinator scores all of the student papers (Prob/Stat). Both of these techniques ensure that the same standards are used across student responses. Since the course coordinator often has more control over test development and scoring than do the other instructors, the question emerged as to whether the coordinators' students have an advantage that would be reflected through final grades. To test this hypothesis, the grades that were assigned in coordinator and non-coordinator sections were compared across nine semesters.

At the end of each semester, students at CSM complete course evaluations that contain 14 standard questions. Key questions from these evaluations over the last nine semesters were examined and compared between the coordinator and non-coordinator sections. To acquire further feedback, three additional surveys—Student Survey, Senior Survey, and Faculty Survey—were developed and administered for the purpose of this study in the Spring 2005. The Student Survey was administered at the end of the semester in all coordinated courses. The Senior Survey, which included many of the same questions as the Student Survey, was administered to graduating seniors. The Faculty Survey was administered to faculty participating in the coordinated courses.

Results

The assessment instruments used, namely grade analysis, course evaluations, and Student, Senior and Faculty Surveys, are described below.

Grade Analysis

This analysis compares 2,055 grades assigned to students by coordinators and 6,978 grades assigned by non-coordinators over nine semesters. These grades fell into the following categories: A, B, C, D, F, W and INC, where W indicates that a given student withdrew from the class, and INC indicates that the student received an incomplete for the course. For each grade category and within coordinator and non-coordinator groupings, the proportion of students that received a given grade was calculated from the total number of assigned grades in that group. These proportions were statistically compared using a one-tailed *z-test* for proportions. Table 2 summarizes the number of students in each category, the hypothesis tested, and the resultant *p*-value.

As Table 2 indicates, only two statistically significant results were found. Coordinators ($p \approx .26$) assigned a higher proportion of A's than did non-coordinators ($p \approx .22$). Non-coordinators ($p \approx .04$) had a higher proportion of students withdraw from the class than did coordinators ($p \approx .02$).

Course Evaluations

As was discussed earlier, student responses to a selection of questions that appeared on the course evaluations were compared between the coordinator and non-coordinator sections over a period of nine semesters. Each student within a given section responded with one of the following to the statements listed in Table 3: *Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree,* or *Not Applicable.* For each, a one-tailed *z*-test for proportions was used to compare the proportion of students that responded with Strongly Agree in the coordinator and non-coordinator sections. The hypothesis tested for each statement is as follows:

H_o: $p_C \leq p_N$: The proportion of Strongly Agree responses in coordinator sections is less than or equal to the proportion in the non-coordinator sections.

H_1: $p_C > p_N$: The proportion of Strongly Agree responses in coordinator sections is greater than the proportion in non-coordinator sections.

Given the large sample size, it is not surprising that all of the tests were found to be statistically significant with a *p*-value less than .01. The final question on the survey asked the following, "Overall would you consider this instructor: A-*Superior*, C-*Average*, E-*Poor.*" Once again, a one tailed *z*-test for portions was used to determine whether the coordinators acquired

Table 2
Statistical Comparison Based on Assigned Grades

Grade	Coordinator p_c	Non-Coordinator p_N	Hypothesis	*p*-value
A	.26	.22	H_o: $p_C \leq p_N$ H_1: $p_C > p_N$	.0004*
B	.33	.33	H_o: $p_C \geq p_N$ H_1: $p_C < p_N$	.3707
C	.25	.25	H_o: $p_C \geq p_N$ H_1: $p_C < p_N$	.4052
D	.10	.11	H_o: $p_C \geq p_N$ H_1: $p_C < p_N$	.1562
F	.05	.05	H_o: $p_C \geq p_N$ H_1: $p_C < p_N$	.1562
W	.02	.04	H_o: $p_C \geq p_N$ H_1: $p_C < p_N$	.0007*
INC	.00	.00	Too small to test	--

W: Withdraw, INC: Incomplete, C: Coordinator, N: Non-Coordinator,
p: proportion, *: statistical significance for α=.01

Table 3
Student Evaluations with Rating of Strongly Agree

Statement	Coordinator		Non-coordinator	
	n	p	n	p
Course material is well presented.	1624	.57	4994	.33
Complex material is well explained.	1614	.51	4991	.31
Assignments are relevant.	1631	.53	4969	.43
Examinations cover important rather than trivial course material.	1636	.47	4983	.35
Grading is fair.	1636	.45	4969	.37
The instructor knows the course material.	1638	.79	4962	.56

n: number of respondents, p: proportion of respondents that Strongly Agreed a rating of Superior at a higher proportion than the non-coordinators. This test also resulted in a statistically significant difference between coordinators (n=1638, p=.73) and non-coordinators (n=4976, p=.50) with a p-value less than .01. In summary, the coordinators consistently received higher ratings from students than did the non-coordinators.

Student Survey

The Student Survey was administered in each of the coordinated courses at the end of the spring 2005 semester. The first question on the survey asked the students which section and course they were completing. A summary of student responses to the remaining questions, grouped by whether a student was in the coordinator's section or a non-coordinator's section, is displayed in Table 4. As this table suggests, across courses, a higher percentage of students within the coordinators' sections agreed with each of the provided statements. Another observation that can be made is that, with the exception of Cal II, students in the coordinator sections judged the course to be better organized than did students in the non-coordinator sections.

Senior Survey

In the spring 2005, graduating seniors were asked to complete an extended version of the survey that was administered in the coordinated courses. The purpose of this survey was to solicit feedback from prior students concerning their experiences with respect to coordinated courses. The first question on the survey asked the students to identify the course that they were considering while completing the survey, and the third question asked whether their instructor was the coordinator. Unfortunately, only three students who knew they had been in the coordinator's section of the course and only seven students who knew they had been in the non-coordinator's section of the course responded to this survey. Due to the small response rate, meaningful comparisons across these groups could not be made. Therefore, Table 5 provides a summary of the responses across both groups. With the exception of one question, the majority of students agreed with each given statement. The exception was that the majority of respondents did not feel that the coordinated courses were better organized than the non-coordinated courses.

Faculty Surveys

In spring 2005, all faculty who participated in the coordinated courses were asked to respond anonymously in writing to two open-ended questions:

1. What recommendations would you make to improve coordinated courses?
2. Do you have any concerns with regard to coordinated courses?

Table 4
Responses to Student Survey

	Coordinator		Non-coordinator	
	n	%	n	%
Course	Responses	Agree/Yes	Responses	Agree/Yes
Question 2: Were you aware that the syllabus and tests for this course were the same across all sections of this course regardless of the instructor? Yes/No				
Cal I	56	100.0	49	98.0
Cal II	66	98.5	203	94.1
Cal III	60	98.3	23	100.0
DEq	62	96.8	183	96.7
Prob/Stat	70	92.9	77	96.1
All	314	97.1	535	95.9
Question 3: The common syllabus that was used across the different sections of this course ensured that I learned the same concepts as my friends who had different instructors for this course. Agree/Disagree				
Cal I	56	89.3	50	92.0
Cal II	66	97.0	199	91.5
Cal III	60	91.7	23	56.5
DEq	62	83.9	181	80.1
Prob/Stat	70	81.4	77	94.8
All	314	88.5	530	86.6
Question 4: The common examinations that were used across the different sections of the course provided a fair method of evaluating my performance within this course. Agree/Disagree				
Cal I	56	91.1	49	95.9
Cal II	66	93.9	201	89.6
Cal III	60	98.3	23	65.2
DEq	62	82.3	182	90.1
Prob/Stat	70	90.0	76	68.4
All	314	91.1	531	86.3
Question 5: This course, in general, was better organized than most instructor-prepared courses. Agree/Disagree				
Cal I	56	87.5	57	68.4
Cal II	64	79.7	199	88.4
Cal III	60	91.7	23	65.2
DEq	61	77.1	176	70.5
Prob/Stat	70	71.4	72	66.7
All	311	81.0	527	76.3

Of the 12 faculty who responded to question one, six indicated that more interaction was needed between the coordinators and the non-coordinators. Feedback included suggestions either to have more team meetings or start having team meetings to acquire greater feedback from instructors concerning test development and scoring, to increase the coordination in terms of the examples completed in class, and to acquire

Table 5
Senior Responses to Student Survey

	Number of Responses	% Agree/Yes	
Question 2: When you were taking the coordinated course that you selected in question number one, were you aware that your syllabus and tests were the same across all sections of the courses regardless of the instructor? Yes/No			
Response	17	94.2	
Question 4: The common syllabus that was used across the different sections of the course ensured that I learned the same concepts as my friends who had different instructors for the same course.			
Response	18	88.9	
Question 5: The common examinations that were used across the different sections of the course provided a fair method of evaluating my performance within the course.			
Response	18	83.3	
Question 6: The common final that was used across the different sections of the course provided a fair method of evaluating my overall performance within the course.			
Response	18	88.9	
Question 7: The course was effective in providing me with a strong background in the mathematical concepts that were necessary to complete the mathematics courses that followed.			
Response	18	77.8	
Question 8: Coordinated courses, in general, are better organized than most instructor-prepared courses.			
Response	16	43.8	

greater agreement and understanding from team members concerning the objectives of the course. Four of the faculty felt that no change was needed in the coordinated courses, and two faculty indicated that there should be a strict adherence to the course syllabus in coordinated courses.

In response to the second question, four of the 12 faculty respondents raised concerns with regard to coordination. All four indicated that coordination greatly limited the freedom and creativity of the non-coordinating instructors. Criticisms were also raised as to the appropriateness of one person making decisions for the entire group, especially when feedback was not acquired from that group. One faculty member stated, “Suggestions for improvement or change are quickly disregarded by the coordinator. There needs to be more of a coordinated effort and less of a top down design.” Four other faculty members indicated that they had no concerns with respect to coordination. One faculty member wrote, “I think, in general, that coordination in the calculus sequence has been institutionalized sufficiently, and it is done well and fairly.”

Discussion

Based on the results reported in Tables 4 and 5, the majority of students within the coordinated courses recognized the benefit of coordination. Across most sections, students displayed strong agreement that the common syllabus and examinations ensured that similar concepts were learned across sections (Table 4, question 3; Table 5, question 4) and that evaluation of student performances was fair (Table 4, question 4; Table 5, questions 5 & 6). One exception to this observation was in Cal III. As indicated in Table 4, only 56.5% of students in the non-coordinators' sections of Cal III agreed with question 3 and only 65.2% agreed with question 4.

During spring 2005, an unusual situation emerged within the non-coordinator sections of Cal III that may explain the observed result. One of the instructors became ill and took sick leave mid-term. The two sections that this instructor taught were taken over by another instructor for the remainder of the term. This unavoidable shift in instructors most likely resulted in a disruption in the consistency of the instruction that students received. Both teacher and students had to become acquainted while continuing to move forward with new material. The impact of this situation may be reflected further in the reduced agreement that is witnessed in Cal III in response to Table 4, question 5 (organization of the course).

The reader will also notice that, as reflected in Table 4, students in Prob/Stat had lower agreement than the majority of other courses with respect to questions 4 and 5. Question 4 refers to the fairness of common examinations and question 5 refers to the organization of the course. Prob/Stat was the only course in which the feedback acquired from instructors, as reported in Table 1, was very limited. Throughout the semester, these instructors met on two occasions for less than a total of 20 minutes, and the course coordinator developed and scored all tests. In other words, not only did the non-coordinators have little opportunity to determine what the coordinator felt were the important components of the course, but they also had little say concerning the concepts on which their students were evaluated.

Examination of the eighth question on the Senior Survey, Table 5, suggests that there was little agreement with the statement that, "Coordinated courses, in general, are better organized than most instructor-prepared courses." This stands in contrast to the strong agreement to similar question asked of the students currently participating in the coordinated courses (see Table 4, question 5). This difference may be partly due to the fact that coordinated courses are required courses completed by students from a variety of majors and backgrounds. These students have less college experience than seniors, and they are completing required courses that precede their major course work. In other words, students currently completing the coordinated courses may be comparing the organizational structure to those of other required courses that precede their major courses; whereas seniors are probably comparing the organizational structure to those of major courses within the department. Most students enjoy their major courses more than the required courses that precede them and, therefore, are likely to evaluate major courses more positively. Another possible explanation of this result emerges from the different backgrounds of the students in the two groups. Students who are early in their academic careers and who are not necessarily majoring in the given subject may find greater benefit in the coordination process than do older students working within their major.

Based on the Student Survey and the Senior Survey, there does appear to be benefit to being in the coordinator's section of a course. For example, for the majority of courses, students judged coordinator sections to be better organized than the non-coordinator sections. Examination of the course evaluations further suggests that students consistently provided higher ratings for coordinator sections than for the non-coordinator sections. Two explanations were considered as potential contributors to this result: 1) coordinators have more experience than do non-coordinators, and the higher ratings reflect this, and 2) coordinators have more control over decision making within the course, allowing coordinators the opportunity to provide more effective instruction.

Within MCS, the first explanation does not appear to be the case. Often, the coordinator is selected based on individual schedules and obligations. In several instances, the coordinator was a second year instructor, and non-coordinators were senior faculty with multiple years of experience. The second explanation appears to be the stronger contributor to the observed result. The coordinator has greater control in changing the course as he or she sees fit. Although the non-coordinator may also make changes, these changes must remain within the constraints set forth by the coordinator. The extent of the benefit to being in the coordinator sections appears to change based on the level of feedback that is acquired from the instructors throughout the course. For example, in Prob/Stat, very little feedback was acquired from the instructors, and this appeared to be reflected in both faculty and student responses to the surveys.

Overall, the grades assigned by coordinators and non-coordinators across nine semesters were similar. The only exceptions were in two categories: 1) more students received A's in the coordinator sections and 2) more students withdrew from the non-coordinator sections. Although both of these findings were statistically significant, from a practical perspective in a 45-person section, the coordinator would assign approximately two more A's than the non-coordinator and the non-coordinator would have one more student withdraw than the coordinator. These differences are not large enough to provide compelling evidence against the benefit of coordination.

Some faculty members expressed their full support for coordinated courses while others raised concerns. The difference between these two groups appeared to be the level of collaboration among the coordinators and non-coordinators. When coordination included continual feedback from all participating instructors, faculty responses to coordination were positive.

When coordination meant that one individual made all or most decisions, discontent emerged from the coordinated group. In other words, effective coordination appears to require strong collaboration between the coordinator and non-coordinators.

The analysis completed here suggests that coordinated courses can be effective tools in the assessment process when coordination is done well. All of the faculty members teaching a course should be active contributors to the design of the syllabus, course instruction, and tests. Moreover, they should be included in the process of evaluating their students; when they are excluded from the decision making process, neither faculty members nor their students indicate strong support for the coordination process.

Prior to this investigation, MCS did not anticipate large differences among coordinated courses. Collaboration was assumed to be an integral part of every coordinated course. Furthermore, course evaluations are considered in tenure and promotion decisions. The results of this study suggest that coordinators may have an unfair advantage in receiving higher ratings on this instrument than non-coordinators. If this instrument is to continue to be used as part of the faculty evaluation process, consideration should be given to the impact of these differences.

This study has recently been completed and, therefore, the results have not yet been used for improvement purposes. In order to ensure that these results are used, two actions are currently underway. First, the MCS Undergraduate Committee has been asked to review this document and the findings concerning the importance of collaboration in coordinated courses. Further, the committee has been asked to propose methods that will be used to prepare future coordinators on effective coordination techniques. Second, the head of MCS has been asked to share this document with the MCS Executive Committee in regard to the potential impact that coordination is having on faculty evaluations.

References

Committee on the Undergraduate Program in Mathematics (CUPM). (1995). Assessment of student learning for improving the undergraduate major in mathematics. In B. Gold, S. Z. Keith, & W. Marion (Eds.), *Assessment practices in undergraduate mathematics* (pp. 279-285). Washington, DC: Mathematical Association of America.

Madison, B. (1991). Assessment of undergraduate mathematics. In L. A. Steen (Ed.), *Heeding the call for change* (pp. 139-162). Washington, DC: Mathematical Association of America.

Moskal, B. (2003). The evolution of an assessment system. *Supporting assessment in undergraduate mathematics*. Retrieved August 25, 2005, from http://www.maa.org/saum/new_case.html

Moskal, B. (2005). The development, implementation and revision of a departmental assessment plan. In L. A. Steen (Ed.) *Supporting assessment in undergraduate mathematics* (pp. 149-155). Washington, DC: Mathematical Association of America.

National Council of Teachers of Mathematics (NCTM). (1995). *Assessment standards for school mathematics*. Reston, VA: Author.

Olds, B., Moskal, B. & Miller, R. (2005). Assessment in engineering education: Evolution and trends. *Journal of Engineering Education, 94* (1), 13-25.

Steen, L. (1999). Assessing assessment. In B. Gold, S. Z. Keith, & W. Marion (Eds.), *Assessment practices in undergraduate mathematics* (pp. 1-6). Washington, DC: Mathematical Association of America.

CHAPTER 10
ENSURING LEARNING IN GATEWAY MATHEMATICS THROUGH ASSESSMENT: STUDENT-CENTERED, COST-EFFECTIVE, AND SUCCESSFUL

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Introduction

In 2005, a major qualitative research analysis described 20 colleges and universities that have achieved high levels of student success due to their effective educational practices (Kuh *et al.,* 2005b). The comprehensive study highlighted the importance of faculty beliefs that students can learn and that faculty have a significant role in ensuring student success by demonstrating high expectations, requiring challenging and collaborative work, and guiding students to sources of academic support. This study, called Project DEEP (Documenting Effective Educational Practice), included analysis of data from the National Survey of Student Engagement (NSSE) and campus site visits to better understand what these effective colleges and universities were doing. The NSSE framework for student success also emphasized several institutional characteristics as helping to explain their success: a spirit of positive restlessness, a bent toward innovation and constant experimentation, a commitment to continuous monitoring, data-driven decision making, and especially "leadership in all corners" (Kuh, Kinzie, Schuh, Whitt, *et al*., 2005a).

This chapter examines the experiences of a Project DEEP campus, The University of Texas at El Paso (UTEP), in institutionalizing a difficult conceptual and operational change in one of its "gatekeeper" courses, precalculus, which had become a significant barrier for students interested in science and mathematics careers. Among the UTEP findings are the vital role of leadership in all corners and the necessity of a faculty champion. Nonetheless, one can also conclude that leadership for change requires a sense of realism about faculty attitudes and reward systems. Not all individuals want change. Identifying potential innovators is critical, as is engaging those who are not threatened by the possibilities of continuous improvement through careful assessment of student learning. This also suggests that academic administrators must have the courage to risk support of innovators and to reward their achievements through appropriate public recognition. Accepting responsibility for student learning while maintaining academic standards is difficult but exhilarating work.

Gatekeeper Courses as Barriers

For almost 25 years, observers have criticized college introductory mathematics and science courses as being competitive, exceedingly difficult, and intimidating, primarily because science professors assume that the current generation of high school science students is better trained (*e.g.,* Tobias, 1990). For many first-time college students interested in science and engineering careers, the introductory mathematics course takes on a gatekeeper role (Tobias, 1992; Van Valkenburg, 1990). Adelman (2006) has demonstrated that successful participation in such “gateway” courses predicts which students will ultimately earn college degrees. He also documented that Latino or Hispanic students are less likely to attend high schools that offer trigonometry or calculus than are white or Asian-American students, while students from economically disadvantaged families are much less likely to be in schools that offer any mathematics above Algebra II than are more economically privileged students.

Thus, these initial college mathematics courses frequently block interested students from entering science, technology, engineering, and mathematics (STEM) degree programs, thereby eliminating students who are judged, perhaps inaccurately, as lacking the analytical ability to become competent scientists and engineers because they could not pass the gatekeeper courses. The pool of degree program majors and baccalaureate recipients decreases, possibly creating a shortage of both scientists and potential future faculty members in STEM fields.

Faculty in numerous disciplines, but especially science, have been engaged in debates about the function of their introductory gatekeeper courses and indeed how to improve student learning generally in large-enrollment courses while managing the costs of undergraduate instruction (Twigg, 1999). These faculty members have attempted to re-conceptualize the role of the introductory courses as that of a *gateway* course rather than a gatekeeper barrier or filter. Institutional problems frequently resulting from gateway courses are summarized in Figure 1. The function of a gateway course should be that of a pump or springboard: to motivate and prepare entering students to succeed in the curricular sequence, thus increasing both the number and quality of students who will major in and graduate from the institution’s academic programs.

Other colleges and disciplines also face similar issues. Colleges of business, for example, find that the accounting course may dramatically reduce the number of their majors, while colleges of liberal arts frequently see first-time students stumble in courses requiring significant reading assignments and writing skills, such as English composition, Western civilization, history, or political science. Given the lack of agreement about the function of these introductory courses, however, faculty who engage in curricular and instructional changes to improve student learning face demanding evaluation questions.

Figure 1

How do gateway course grades become an institutional problem?

- **Students' anger** about remediation costs in time and money, their frustration about tediousness of the content and instruction, but also about high failure rates and the necessity of multiple retakes.
- **Faculty's frustration** about students' lack of content knowledge and skills and instructor concerns about maintaining standards of excellence.
- **Faculty's negative perceptions** that the gateway course functions as a barrier to enrollment and success in the major(s).
- **Administration's fears** about costs to the campus and to students, parents, and taxpayers, and associated public relations issues.

The Role of Assessment

Literature on science curricular and instructional reform contains data from a variety of evaluation methods. These range from anecdotal evidence (Coppola, 1995; Magner, 1996) and proposals for effective evaluation methods without data (Dally & Zhang, 1993; Prabhu & Ramarapu, 1994; Seltzer, Hilbert, Maceli, Robinson, & Schwartz, 1996; Willemsen, 1995) to student satisfaction ratings of new courses (Johnson & Leonard, 1994; SUCCEED Project, 1996; Woods, 1996). Others have reported student course retention and failure rates (Felder, Forrest, Baker-Ward, & Mohr, 1993; Luck & Stephens, 1992; Osborne & Fullilove, 1993; Ratay, 1992), while some used student course and final examination grades (Davis & McCoullum, 1992; Hershberger & Plantholt, 1994; Johnson, 1995; Lomen, 1992; Penn, 1994; Tidmore, 1994; Woods, 1996). Some studies attempt to incorporate aspects of several of these approaches (Felder, Felder, Mauney, Hamrin, & Dietz, 1995), including analysis of the match between students' expectations and their actual experiences (Johnson & Leonard, 1994). There are useful references for creative approaches to assessment of undergraduate learning in science courses (Adelman, 1989), minority students' performance in mathematics (Moreno, Muller, Asera, Wyatt, & Epperson, 1999), and linking assessments of the general learning of graduating seniors with their previous coursework (Ratcliff, 1994; Ratcliff & Jones, 1993).

Evidence from science and mathematics course innovations, however, is often limited in two significant ways. First, some observers challenge approaches that compare course grades, questioning whether innovative professors may have eased the academic rigor of the course and/or lowered the standards, thereby fostering grade inflation (Rosen & Klein, 1996). Some critics of the Harvard reform calculus model[1], for example, contended that those calculus courses were watered down in an attempt to make calculus more relevant to undergraduates (Wilson, 1997). Second, student satisfaction ratings of new courses may offer useful suggestions, but they do not provide an objective measure of learning and skills development, nor do they predict future academic success. Many of the evaluation case studies may not generalize, and few offer a systemic approach to or model for the evaluation of curricular and instructional improvement. In addition, growing concerns about the academic success of minority students have generated a number of complex conceptual models to analyze gateway course access and outcomes (e.g., Bensimon, 2004). In contrast, efforts at UTEP to improve student learning and outcomes in precalculus provide a useful example of how to use assessment to support and defend an innovative mathematics initiative.

UTEP's Gateway Mathematics Course Problem

For many commuter institutions of higher education, and especially those that serve a significant percentage of minority or first-generation college students, the precalculus course is often a prerequisite for capable yet under-prepared high school graduates who aspire to careers in science and engineering. Because their secondary schools may not have provided a sufficiently rigorous mathematics curriculum or learning experiences, many students may not score sufficiently high on their college mathematics placement test to enroll in calculus. This situation characterized UTEP in the early 1990s, with the majority of first-time freshman students who were interested in STEM majors being required to take precalculus as their first college mathematics course. Many were not successful in that effort. In addition, UTEP is a Hispanic-Serving Institution (in fall 2004, about 75% of its freshman were of Hispanic, primarily Mexican-American, origin), and like many public institutions (National Science Foundation (NSF), 2000), it was particularly concerned about student achievement in the introductory mathematics courses.

Because the mathematics faculty viewed entering students as especially under-prepared, the Department of Mathematical Sciences had institutionalized a two-course precalculus sequence, four semester credit hours (SCH) each, making the pathway even longer to reach a science or engineering degree program. Frustrated by the large number of UTEP entering students who did not pass the two precalculus courses or calculus, the chair of the department decided to undertake an extensive curricular and instructional reform effort, including the implementation of Harvard calculus reform courses beginning in fall 1994. Simultaneously, a full-time lecturer volunteered to design a modular approach to precalculus.

Possible Student Outcomes in a Gateway Course

For more than two decades, higher education has debated and documented the importance of assessment of student learning (Banta, 1994, 1999; Ewell, 1999, 2005; Hutchings & Shulman, 1999; Marchese, 1999). There is common agreement about the importance of faculty involvement in assessment, but there are fewer examples of effective faculty engagement. Most faculty have had little assessment or program evaluation knowledge or experience, yet they are expected to address assessment and evaluation issues in addition to their teaching assignments (Beaudry & Bruce, 2003).

To evaluate the impact of curricular or instructional innovations on student learning, faculty have traditionally looked at course grades (*i.e.*, pass rates) as the primary measure of curricular or instructional improvement. Assuming no significant variations in students, two reactions to course grades are possible. A high failure rate may imply high academic standards, or it may indicate curricular and instructional problems. Similarly, an increase in pass rates could be interpreted as the result of lowered standards, or it could reflect a more coherent curriculum and/or improved instructional strategies. The problem in using course grades as the primary indicators is that this approach cannot resolve such issues.

An additional issue of having a primary focus on course pass/fail rates is that it ignores student patterns in terms of withdrawal, requesting an incomplete grade, repetition of the course, and other behaviors that indicate whether the course is achieving its purpose. Using course grades may also fail to distinguish between the academic achievement of students attempting the course for the first time and those who are repeating it (some for three or more times), thus blurring the effects of innovation. The probability of freshman students being caught in a circular trap of early withdrawals, extended periods with an incomplete grade, or a completed course with an unsatisfactory grade of a D or F is typical of such courses. This makes assessment of the impact of such a course or efforts to improve its effectiveness highly complex, and an individual faculty member seldom has the time or resources to initiate and maintain the longitudinal tracking process to achieve such an effort. In addition, it takes a fairly significant institutional effort to build an assessment program to support faculty interested in assessment (Beaudry & Bruce, 2003). Thus, a departmental effort and/or external resources are required to do an effective evaluation (Andrade, 2001).

The UTEP mathematics chair realized that a longitudinal evaluation model would be required to validate any such initiative, since colleagues might be quick to challenge improvements in grades as resulting from a watered-down curriculum and/or instructor sympathy. The mathematics lecturer who was appointed program director proposed, therefore, the radical concept that gateway course curricular and instructional reform could not be evaluated by the course's pass rates, but rather that the only valid measure would be students' grades in the third course in the curricular sequence, calculus—and that if a gateway course were to be judged effective, the majority of students who completed it should be able to pass the targeted course in the sequence on the first try. The chair enthusiastically accepted this definition of success and the potential value of an external evaluator who could provide valuable longitudinal data to assist in guiding the program. Figure 2 lists steps to be taken in improving a gateway course.

Figure 2

Recommended Steps for Faculty in Improving a Gateway Course

- Obtain data to analyze student performance in the course and to serve as a baseline for longitudinal tracking.
- Determine the philosophy and purpose of the gateway course. Learning is not measured by seat-time-across-semesters; varied time periods are needed to achieve student learning.
- Identify success in the target course in the curricular sequence as the primary measure of success for the gateway course; therefore, the grade in the target course will be the indicator of effectiveness of the reform.
- Seek assistance from the institutional research office to design the method for student tracking and to determine the successful outcomes for cohorts of first-time attempters only.
- Identify the cohorts and tracking period as the initiative begins.

Given the department's challenge of how to evaluate such a premise, in 1994, the UTEP Center for Institutional Evaluation, Research and Planning used research from the University of Puerto Rico (Piñero, 2000) to design and pilot the Indices of Course Efficiency and Effectiveness (ICE^2) model to study the student outcomes of the precalculus course. Andrade (2001) charted the flow of first-time attempters through this gateway course, and the model has continued to document student outcomes at UTEP (see CIERP Projects - ICE[2] 2005 at http://irp.utep.edu/).

Getting Started in a Course Reform Initiative

In the late 1980s, the mathematics lecturer volunteer began contacting students who failed Precalculus I, the first of the two-course precalculus sequence, to determine why. She documented reasons that each one felt she or he had failed. After several years of interviews, the instructor began to identify several common explanations:

1) First-time freshmen who had just graduated from high school did not get serious about their university mathematics course for three to four weeks. By that time, they were too far behind to catch up.
2) Students frequently got stuck on one unit in the course and could not proceed beyond it to the next unit.
3) Students did not want to admit they needed help with the material.
4) Students felt isolated.

In response to these attitudes and behaviors, she decided to design a precalculus course that focused on student success and that targeted students who were slow to become motivated, had less skill in some areas, and felt isolated or did not know how to seek assistance. A modular format would address the slow starters and those weak in some areas. To address feelings of isolation, she created group projects where students were forced to work in teams outside of class. Finally, anticipating faculty concerns in the department that such efforts would water down the course, the course requirements were made even more rigorous.

In 1992, she asked permission of the chair and then the department's curriculum committee to pilot a modular program where the semester was divided into four distinct time periods, with the course curriculum divided accordingly. They agreed, the chair designated the lecturer volunteer as the program coordinator, and the coordinator recruited three additional faculty members to participate. With the backing of the chair, the program coordinator also began to informally interview other faculty in the colleges of science and engineering about their expectations for students' entry-level mathematical knowledge and skills necessary for success in lower-division laboratory classes. She learned that the precalculus courses were not sequenced appropriately for the science and engineering students' concurrent laboratories.

The instructor group decided on a pilot time period of three years. Half the sections of the precalculus course would be taught in the traditional format, and the other half would be taught in the modular format. At registration, students would not know the format of their section. The pilot started with four sections, each taught on the same days at the same class period so that students could move from one course to another without a scheduling problem.

All students would start module 1 during period 1 of the fall 1993 semester. Those students who passed module 1 during period 1 would move to a class that taught module 2 during period 2; those students who did not pass would retake module 1 during period 2 with no grade penalty. During period 3, students would be taking modules 1, 2, or 3 depending on what modules they passed. Students would be given three tries to pass each module. If they failed one module three times, they failed the course. Those students who did not pass all the modules during the semester would be given an In-Progress Grade of “P” and would be required to register for the course the next semester to continue the course. Those students who did not register for the course in the next semester would have their “P” grade changed to “F.” A graphic display in Figure 3 of the model demonstrates the pathways and potential options for students to persist in their efforts to learn (Marcus, 1999).

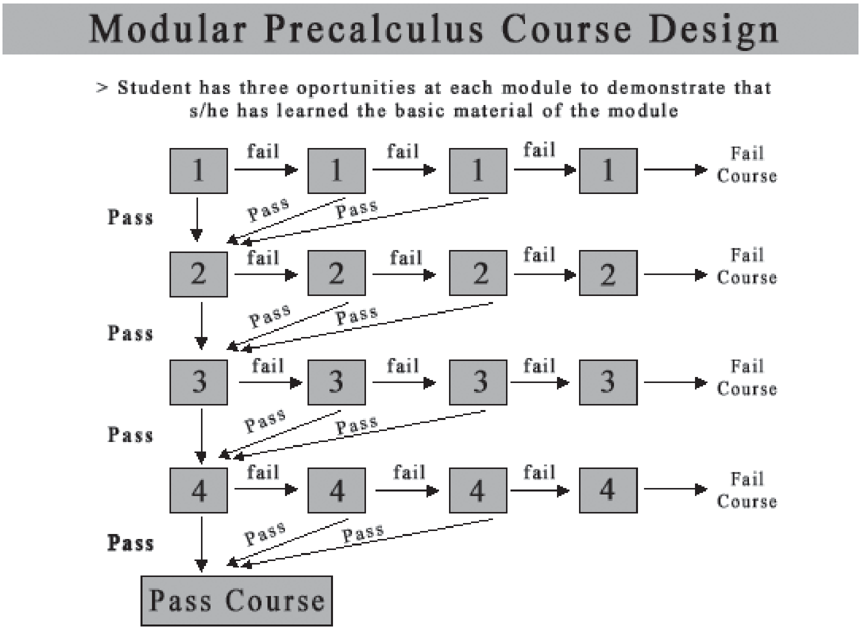
Funding from an existing NSF grant to the university enabled the program director to hire six peer facilitators who were available in a center called Math Lab, Monday through Friday, 8 p.m. to 5 p.m., specifically to assist students who were experiencing difficulties in the modular precalculus classes. In addition, during the pilot’s first semester, three faculty members decided to create an online tutorial for students who had difficulties coming to campus to seek help from their professors (*e.g.,* those with off-campus jobs, significant family responsibilities, or transportation problems). The faculty asked students to list the top five topics they wanted to see on the web with practice problems. Based on their feedback, the faculty team created SOS Math at http://www.sosmath.com/, and it has continued to serve as a significant resource for not only UTEP students but also individuals from around the world.

After the first semester, the program director was tempted to abandon the project; the overall pass rate was only 20%, below even the historic average of 40%! Nonetheless, she and the instructional team decided to persist at least to the end of the third year. During the second semester of the pilot, they increased the number of sections to six. Four of the sections started at module 1, one section started at module 2, and one section started at module 3, while module 4 was not offered until period 2.

Student Feedback, Instructor Development, and Curricular Change

At the end of each time period, all students were invited to complete a survey to describe what they liked most about the course, what they disliked most, what they would leave out if the course were redesigned, what they would keep, and any ideas they had for improving the design. The student surveys provided invaluable information that allowed the faculty to fine-tune

Figure 3



the design. For example, using feedback from students, they reduced the number of group projects in each module from three to one. The faculty learned that half of the students in a group project would pass a module, while the other half failed. Informal interviews uncovered the frequent reason that two individuals in the group project did the work, while the other two went along for the ride. Based on these findings, the instructors instituted a requirement that on the day projects were due, in-class presentations would be conducted with a random selection of members to defend their team's project. This presentation would count as half of the project grade. And finally, based on those interview results, the instructors permitted students to "fire" team members because they were not contributing.

Student feedback also led to some other highly innovative changes. During the second semester, students who completed the course mid-semester petitioned that they be allowed to retake modules to try to increase their overall grade. The instructional team agreed and included this modification in the design. The faculty also noticed that students in groups who had the same majors outperformed other groups. They redesigned the group selection process so that, whenever possible, the groups contained students with the same majors. In addition, faculty pooled office hours so that any student attending a modular precalculus course could go to any instructor teaching a modular section for help.

As another component of the process evaluation, the program director had regular meetings with the instructors and peer facilitators to determine where the precalculus students were having trouble. She sought to foster a spirit of egalitarian dialogue and constructive problem solving in reaction to members' observations about student progress. For example, if peer facilitators reported that they were getting a heavy load of students coming in for help with the topics of inequalities, all instructors would start emphasizing inequalities in their classroom work.

As a major innovation, the instructional team created common or uniform examinations for each module during each time interval. These examinations required instructor review and grading (*i.e.*, they were not multiple-choice questions that could be graded electronically). This step allowed the program director to monitor examination grades, percent passing, and the percent of those successful students who passed the next module. She would then give feedback to the entire group and especially to instructors whose students were not performing as well as those in other classrooms—and to those instructors whose students had passed yet who failed the following module, which suggested that the students had not actually learned the prerequisite concepts and skills. These discussions further provided her an opportunity to mentor the precalculus instructors, sometimes offering instructional tips, other times making suggestions on how to encourage first-generation students, many of whose home language was Spanish, and at times actually demonstrating good teaching and group facilitation practices. These collegial instructional team meetings, in which any of the individuals could reflect on the implications of the assessment data and could offer suggestions on effective instructional practices, generated a spirit of trust and growing confidence, because the issues discussed were not shared with the chair or other faculty.

Within two years, the results were so encouraging that the department voted to end the pilot and to formally adopt the modular design for all Precalculus I classes. During this next phase of curricular innovation, the faculty team observed that several students who had completed Precalculus I during one semester had enrolled in Calculus I the following semester. When asked what happened to the requirement for first completing Precalculus II, students replied that they had placed out of it by passing the university's Mathematics Placement Examination. The program director began to systematically track the performance of students who placed out of Precalculus II and to compare their progress with students who took the required next course of Precalculus II. Because she found no difference in the two groups' performance in Calculus I, she recommended to the department that the two precalculus courses of four SCH each be combined into one precalculus course of five SCH. The faculty agreed, and this shortened the mathematics requirement by one semester and encouraged persistence in science and engineering degree plans as well as contributed to a more efficient time-to-graduation measure.

After each modular time period, the department administered voluntary three-hour test-out examinations that replaced the grade of a particular module if the test-out grade was higher than the grade received in class. Students saw this as an additional opportunity to demonstrate their knowledge in those instances when they “really knew the material but had a bad day,” and the option appeared to motivate them to continue to work hard with the goal of passing that module. The instructional team noticed that students were taking, on average, five attempts to pass the four modules. The program director, therefore, began offering module 4 online between semesters and, following positive results, started offering organized classes between semesters.

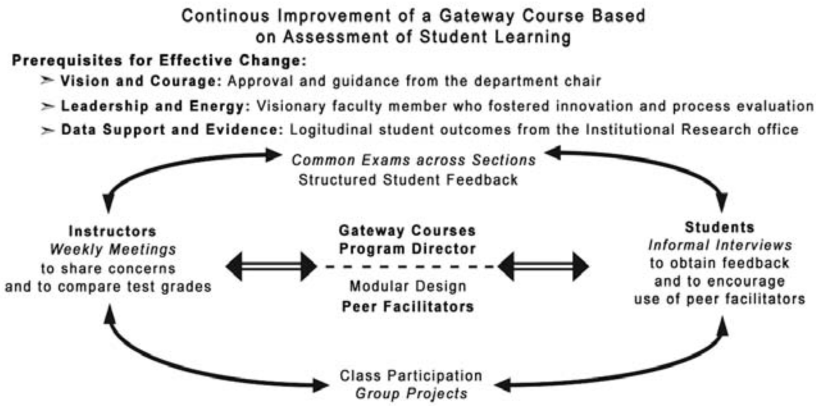
In 2004, Calculus I was modularized at UTEP, and students who passed precalculus mid-semester were permitted to enter into Calculus I, starting the course in the middle of the semester with the first module. The department is in the process of creating online practice examinations for each calculus module, as well as proctored online official examinations for each module. Preliminary data on the first year success of the modular Calculus I pilot are encouraging: 92% of the students passed in the first semester, and 98% of the students passed by the end of the second semester. As in the original pilot process, the program continued to administer narrative evaluation sheets to the students after each module so that the faculty can fine-tune the program based on student feedback, in addition to the evaluation outcomes provided by the longitudinal tracking of student success.

Results: What Happened?

The university’s Department of Mathematical Sciences engaged in three phases of curricular and instructional innovation over several years in an effort to improve student learning in the precalculus course. Prior to the curricular reform, students had to complete Precalculus I and Precalculus II, each a four SCH course, thus requiring two semesters of study before they proceeded to Calculus I. In fall 1994, the four SCH pilot Precalculus I course began a new modular approach, with a comprehensive evaluation process that included intensive student and instructor feedback. For the next four years, students were still required to complete the second four SCH course of Precalculus II before they could proceed to Calculus I. The success of the pilot modular curriculum led the Department to create a new precalculus course, in fall 1998, by compressing the former two courses that were four SCH each into one five SCH precalculus course that could be completed in a single semester.

Apart from analyzing examination results, student feedback, instructor concerns and semester grades, the program director used the precalculus evaluation model and its longitudinal tracking effort to examine annually the

Figure 4



overall progress of each fall cohort of first-time attempters. The process is illustrated in Figure 4.

As noted above, there were definitely minor crashes and breakdowns on the road to improvement. Nonetheless, beyond saving student time and money, the ongoing program results have been dramatic. From the university's perspective, one of the most significant contributions of the precalculus initiative has been an expanded pool of potential STEM students, which occurred within a long-standing context of declining or flat first-time freshmen enrollment trends in the precalculus course (an average of about 400 from fall 1993 through fall 1999). The result, after a decade of pilot projects, has been an extraordinary growth in precalculus enrollment of first-time attempters each fall semester—from 396 in fall 1993 to 614 in fall 2003, an increase of 55% (see Figure 5). This is noteworthy, since the enrollment of PreEngineering and PreScience students, the primary market for precalculus, increased by only 43% (754 in fall 1993 in comparison to 1,078 in fall 2003) and the overall enrollment increase at UTEP was only 9%.

In terms of student learning and course outcomes, a comparison of the fall 1993 cohort to the fall 2003 cohort reveals a notable growth in the percent of students who passed precalculus on the first-attempt, from 14.9% to 46.7% (see Figure 6).

Importantly, the total number of first-time attempters who eventually passed that course within a 24-month period grew from 44.7% to 66.8%, with rates of more than 70% in several prior years (see Figure 7). Even more important has been the dramatic rise in the number of successful precalculus students who actually continue on to enroll in Calculus I—increasing from 34.5% in 1993 to 73.4% in 2003 (see Figure 8).

Figure 5
Precalculus Enrollment:
Number of First-Time Attempters Enrolled in the Fall Semester

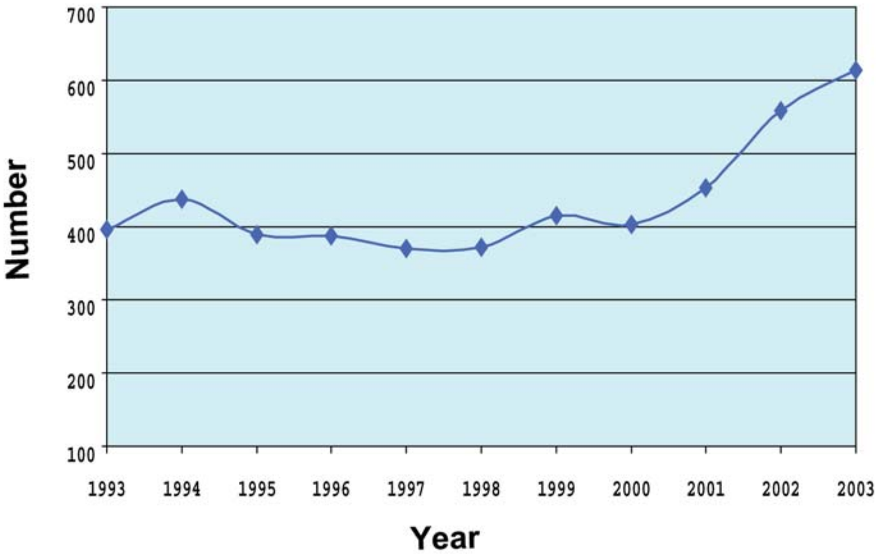


Figure 6
Percent of First-Time Attempters
Who Passed Precalculus on the First Attempt

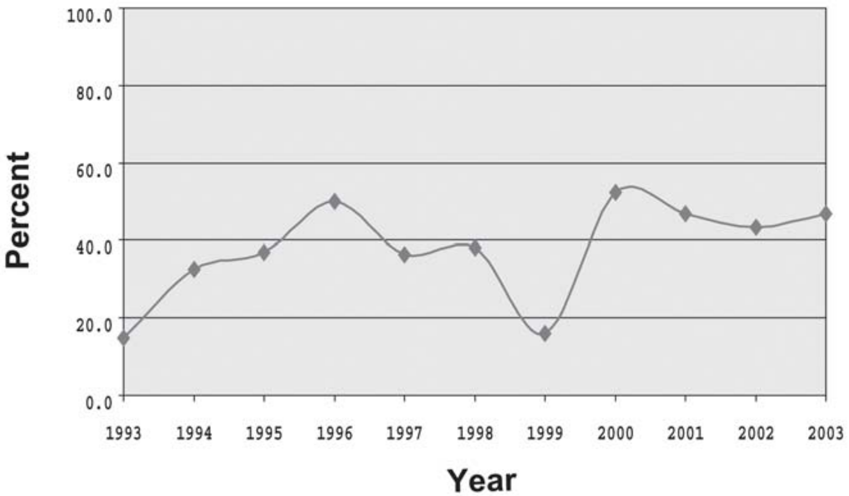


Figure 7
Percent of First-Time Attempters
Who Passed Precalculus in a Two-Year Period

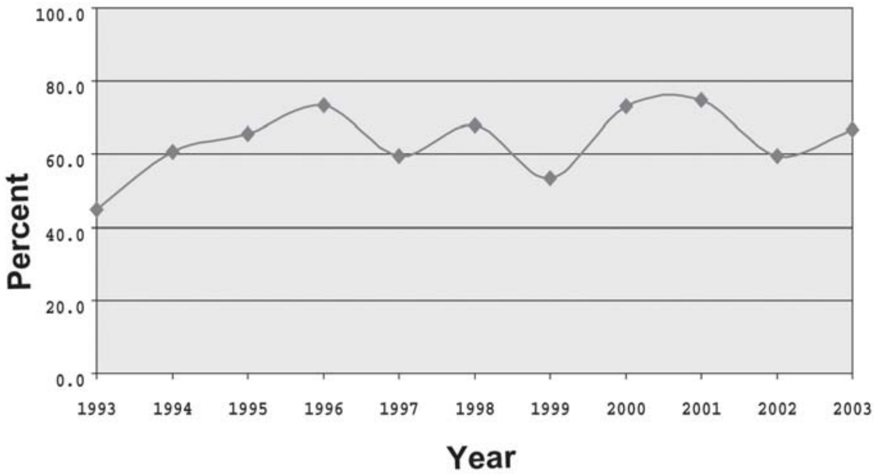
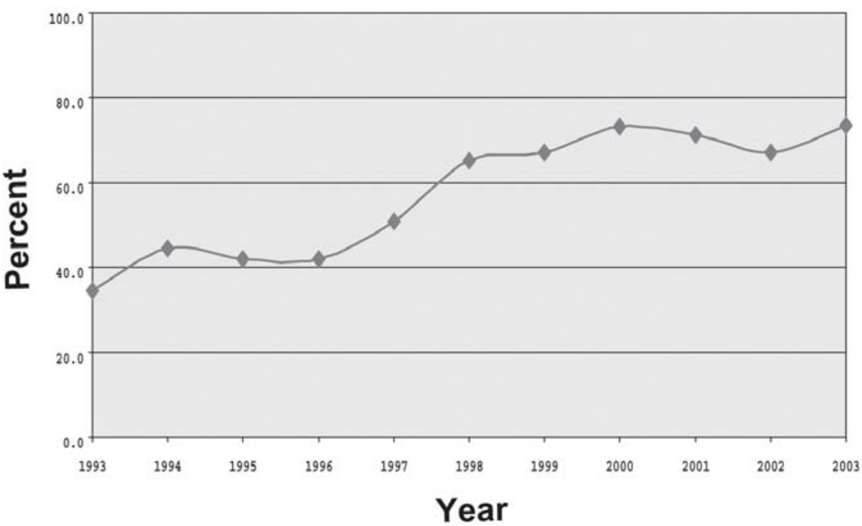
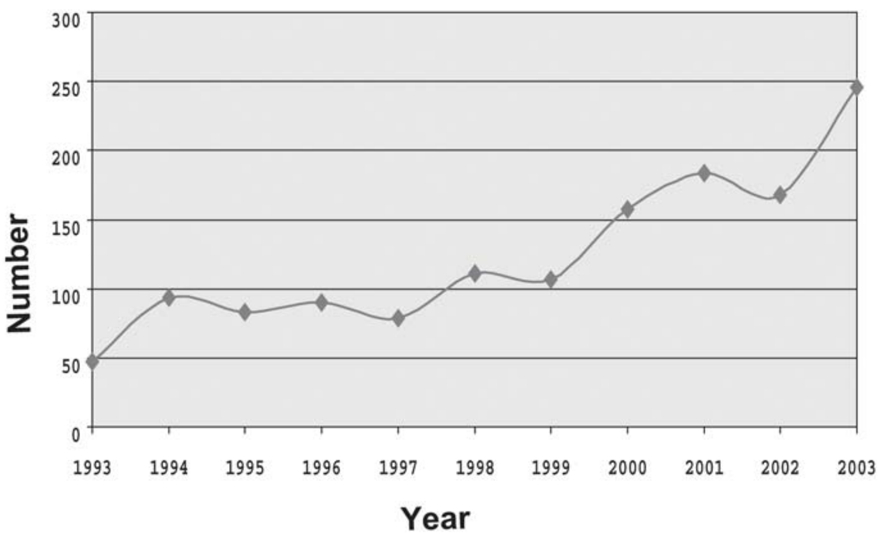


Figure 8
Calculus Enrollment:
Percent of Successful Precalculus Students



Perhaps most significant of all, as shown in Figure 9, the number of students who successfully completed Calculus I, (*i.e.*, the pool of potential science and engineering majors), increased by more than 500% from fall 1993 to fall 2003—from 47 (40 on the first attempt) to 242 students (210 on the first attempt).

Figure 9
Potential Pool of STEM Majors:
Number of Successful Precalculus Students
Who Passed Calculus I



While definitive conclusions about student attitudes and learning cannot be drawn from these data, the larger number and percent of students continuing on to Calculus I suggests that the precalculus curricular and instructional innovations have increased student interest and motivation in careers requiring rigorous mathematical preparation. Similarly, the growth in the number who pass Calculus I on the first attempt, as well as the maintenance of a much higher level of the total percent who pass, suggests improvement in their knowledge and skills.

Cost Benefits Analysis

Institutional consequences of this innovation beyond saving student time and tuition are significant. Typically, lecturers, part-time instructors, and graduate assistants teach gateway courses, at a lower cost to the institution than would be required for tenure-track faculty. Gateway course instructors, however, often receive little or no orientation to the institution and minimal, if any, training about the department's instructional expectations and practices. They are rarely supervised and almost never mentored, not being viewed as valuable an institutional resource as tenure-track faculty. Furthermore, there are minimal rewards for such instructors, in terms of salary, office space and support, or even collegial relations with the tenured faculty.

A department and the institution must assess the cost benefits of using such an inexpensive instructional pool in comparison to the costs represented by high failure rates, introductory course repetitions, and student decisions not to persist in science and engineering majors. In this case, the precalculus program director redefined the role of the gateway course instructors and created a team that not only took ownership of the concepts of fostering student learning through assessment, but also generated a learning environment in which they taught each other how to be better instructors by using assessment data. There was a modest cost for the peer facilitators, but an additional and very significant benefit is that each of them graduated and continued on to an advanced degree program. Thus, the efficiency of less expensive instructors was maintained, but the high costs of student failure were redefined and converted into much more hopeful success rates.

The costs of the evaluation process, both the program director's efforts to collect current student feedback and the institutional costs to track and analyze longitudinal student success, must be considered as well. Chun (2005) proposes that there are essentially three approaches to assessment in higher education, and realistically, a program can aspire to choose only two because of the tensions among them—assessment that is faster, better, and/or cheaper:

- What's faster? Requiring less time to collect data and to complete analyses.
- What's cheaper? Necessitating fewer resources (money, staff, technology, and other materials) to collect the data and complete analyses.
- What's better? Having overall higher quality assessment (admittedly the least straightforward of these terms, but here it is defined as the accuracy and authenticity of the indicators, and the scope of the assessment). (Chun, 2005)

In UTEP's case, the precalculus program director decided from the beginning on a quality approach by committing to a three-year waiting period to assess the overall academic success of first-time course attempters, beyond the faster and cheaper indicators of semester course grades and student satisfaction. The resulting data have demonstrated the effectiveness of the program's innovation. She would argue, however, that it was critical for the instructional team to be prepared to risk failure and indeed to use the longitudinal data to show them when the program occasionally got off track.

While it might be incidental, the authors would also like to point out that the lecturer who became the program director subsequently moved from that tenuous status to a tenure-track position. Further, she received the Chancellor's Award in Teaching in 1998 and was granted tenure in 2000, publicly illustrating the importance that the university placed on teaching innovation and student learning.

In fall 2004, the department began a pilot Calculus I modular course and transferred the directorship of modular precalculus to someone who had not participated in the initial pilot program. Like any innovation, the true test of program effectiveness comes with the transition of leadership, and it remains to be determined if the intensive intervention will be maintained as originally designed and improve over time.

Additional Applications of This Model

Beyond the excitement of the precalculus course outcomes, there is a strong spirit of innovation and self-assessment both in the department and beyond. This was evident in three major projects. First, the university mathematics faculty began an analysis of the complete four-course sequence of introductory mathematics services courses, including the developmental mathematics courses. Second, they initiated discussions with El Paso Community College faculty and administrators about curricular alignment of freshman mathematics courses, using the modular precalculus as a model for discussion and possible replication. Third, the UTEP College of Science partnered with the College of Education to improve the mathematics preparation of students who aspire to become teachers. The College of Science began development of online diagnostic and practice examinations for students preparing to become teachers to strengthen their science and mathematics knowledge and skills before attempting the state's teacher certification examination. In summary, the faculty, dean and provost have demonstrated openness to exploring assessment of student learning and options for instructional approaches that seemed unthinkable a decade earlier. These steps suggest that change indeed begets change.

Conclusion: Is This a Replicable Model?

For three years, the department has piloted a small online version of the modular Precalculus I course, in which students enrolled in the modular course could access any of the modules to review content and practice their test-taking skills and/or to work on completing the final module if they were not able to do so in the regular semester. Data from the longitudinal evaluation model documented that students' performances were adequate, in that about two-thirds of them successfully completed the course.

The UTEP findings suggest that several groups of students may benefit from the extended time period and web-based character of such essential gateway courses. These include commuter students or part-time, working students who cannot stay on campus long enough after class to take advantage of practice laboratories and study groups, as well as students whose first language is other than English or first-generation college students who may lack confidence about their basic skills levels. In addition, many institutions struggle with under-prepared high school graduates, especially in the areas of mathematics and writing. Such issues need to be further explored, because they are relevant to a growing number of higher education institutions. Further, because the percent of students enrolling in college will probably continue to rise, access to gateway courses will need to expand.

An NSF workshop on indicators of success in college science and engineering education quoted Dr. Manuel Gómez, director of the Puerto Rican Louis Stokes Alliance for Minority Participation:

> [He stated that] to bring about effective institution-wide use of assessment data, one must approach each stakeholder group in terms of its values and needs . . . Only when confronted with data on their own students . . . will faculty buy into the conclusions and start to change their department . . . He therefore urged reformers to structure assessment and evaluation information intended for administrators in ways that clearly communicate how educational change is affecting the system . . . Gómez argued that while change makers at the classroom and departmental level are essential, isolated individual efforts ultimately will be rejected by the institution if institutional leaders do not understand the cumulative value of their efforts. (Millar, 1998, p. 28-29).

Failure is expensive in terms of student tuition costs, humiliation, and attrition, but also in terms of faculty frustrations, loss of science and mathematics majors, and potential damage to an institution's public relations. Any freshman gateway course with an unsatisfactory pass rate and/or faculty concerns about student preparation for the essential courses in the science and mathematics curricular sequence warrants the type of intensive, intrusive reform illustrated by this modular precalculus model. This implies, however, that institutional resources must also be available for longitudinal assessment of clearly defined student outcomes, so that faculty innovators will have the evidence needed to convince administrators that the educational changes are indeed successful, both for student persistence and for cost factors. Not all innovations are successful, however, and faculty also need longitudinal research to aid them in adjusting their efforts and, indeed, in making decisions about whether to continue with an experimental approach. But as Kuh and others emphasized, it is this spirit of self-criticism that characterizes innovators who are committed to student academic success, and they continuously “exhibit a persistent tendency to move forward with eyes wide open and alternative strategies in mind to deal with changing circumstances.” (Kuh *et al*., 2005a, p. 51).

Endnote

1 The Harvard reform calculus model is a result of a national effort supported by a National Science Foundation grant in the 1990s to reform calculus instruction in colleges and universities. The model was developed by a consortium of community college and baccalaureate-granting institutions led by faculty from Harvard University.

References

Adelman, C. (1989). *Signs and traces: Model indicators of college student learning in the disciplines.* Washington, DC: U.S. Government Printing Office.

Adelman, C. (2006). *The toolbox revisited: Paths to degree completion from high school through college.* Washington, DC: U.S. Government Printing Office. Retrieved June 21, 2006, from http://www.ed.gov/rschstat/research/pubs/toolboxrevisit/toolbox.pdf

Andrade, S. J. (2001). Assessing the impact of curricular and instructional reform: A model for examining gateway courses. *AIR Professional File*, No. *79.*

Banta, T. W. (1994). Summary and conclusions: Are we making a difference?. In T. W. Banta & Associates (Eds.), *Making a difference: Outcomes of a decade of assessment in higher education* (pp. 357-376). San Francisco, CA: Jossey-Bass.

Banta, T. W. (1999). *Assessment update: The first ten years.* Boulder, CO: National Center for Higher Education Management Systems.

Beaudry, M.L., & Bruce, A.S. (2003). *A campus-wide mission: The scholarship of teaching*. Washington, DC: American Association for Higher Education.

Bensimon, E.M. (2004). The diversity scorecard: A learning approach to institutional change. *Change, 36*, 45-52.

Chun, M. (2005). Faster, better, cheaper: The pursuit of higher education assessment. National Resource Center for the First-Year Experience and Students in Transition. Retrieved June 21, 2006, from http://www.sc.edu/fye/resources/assessment/newessay/author/chun1.html

Coppola, B. P. (1995). Progress in practice: Using concepts from motivational and self-regulated learning research to improve chemistry instruction. *New Directions for Teaching and Learning, 63*, 87-96.

Dally, J. W., & Zhang, G. M. (1993). Freshman engineering design course. *Journal of Engineering Education, 82*, 83-91.

Davis, D. C., & McCoullum, H. W. (1992). A program for retention of first-year minority students in engineering and science. In L. P. Grayson (Ed.), *Towards 2000: Facing the future in engineering education* (pp. 456-460). Nashville, TN: Proceedings of Frontiers in Education Conference.

Ewell, P. T. (1999). Identifying indicators of quality. In M. W. Peterson (Ed.), *ASHE reader on planning and institutional research* (pp. 529-551). Needham Heights, MA: Pearson Custom Publishing.

Ewell, P.T. (2005). Power in numbers: The values in our metrics. *Change*, *37*(4), 10-16.

Felder, R. M., Felder, G. N., Mauney, M., Hamrin, C. E., & Dietz, E. J. (1995). A longitudinal study of engineering student performance and retention. III. Gender differences in student performance and attitudes. *Journal of Engineering Education, 84*, 151-163.

Felder, R. M., Forrest, L., Baker-Ward, E. J., & Mohr, P. H. (1993). A longitudinal study of engineering student performance and retention. I. Success and failure in the introductory course. *Journal of Engineering Education, 82*, 15-21.

Hershberger, L. D., & Plantholt, M. (1994). Assessing the Harvard consortium calculus at Illinois State University. *Focus on Calculus, 7*, 6-7.

Hutchings, P., & Shulman, L. S. (1999). The scholarship of teaching: New elaborations, new developments. *Change, 31*(5), 10-15.

Johnson, G. T., & Leonard, R. J. (1994). Evaluating curriculum changes in a computing service course. *Higher Education Research and Development, 13*, 189-198.

Johnson, K. (1995). Harvard calculus at Oklahoma State University. *American Mathematical Monthly, 102*(9), 794-797.

Kuh, G.D., Kinzie, J., Schuh, J.H., & Whitt, E.J. (2005a). Never let it rest: Lessons about high-performing colleges and universities. *Change, 37*(4), 44-51.

Kuh, G.D., Kinzie, J., Schuh, J.H., Whitt, E.J., & Associates. (2005b). *Student success in college: Creating conditions that matter.* San Francisco, CA: Jossey-Bass.

Lomen, D. O. (1992). Reform calculus: Quick answers to four questions. *Focus on Calculus, 1*, 6.

Luck, S. J., & Stephens, J. A. (1992). An introduction to engineering through a "Freshman Seminar" course. In L. P. Grayson (Ed.), *Towards 2000: Facing the future in engineering education* (pp. 22-24). Nashville, TN: Proceedings of Frontiers in Education Conference.

Magner, D. K. (1996). As enrollments in biology soar, colleges try new approaches. *Chronicle of Higher Education, 43*, A12-A13.

Marchese, T. (1999) Assessment today – and tomorrow. *Change, 31*(5), 4.

Marcus, N.C. (1999). Modular precalculus, clustering, and reform mathematics. *Focus on Calculus*, *16*, 1-4.

Millar, S. B. (Ed.). (1998) *Indicators of success in postsecondary SMET education: Shapes of the future – Synthesis and proceedings of the Third Annual NISE Forum, Workshop Report No. 6.* Madison, WI: University of Wisconsin-Madison, National Institute for Science Education.

Moreno, S. E., Muller, C., Asera, R., Wyatt, L., & Epperson, J. (1999). Supporting minority mathematics achievement: The Emerging Scholars Program at The University of Texas at Austin. *Journal of Women and Minorities in Science and Engineering, 5*, 53-66.

National Science Foundation (NSF). (2000). *Women, minorities, and persons with disabilities in science and engineering: 2000* (September 2000, NSF 00-327). Arlington, VA: Author.

Osborne, E., & Fullilove, M. (1993). The Medical Scholars Program. In D. Marcus, E. B. Cobb & R. E. Shoenberg (Eds.), *Lessons learned from FIPSE Projects II* (pp. 77-82). Washington, DC: U.S. Department of Education.

Penn, H. L. (1994). Comparison of test scores in Calculus I at the Naval Academy. *Focus on Calculus, 6*, 6-7.

Piñero, A. C. (2000). Measuring the effectiveness and efficiency of SMET programs: The index of course efficiency (ICE). A presentation to Historically Black Colleges and Universities representatives, National Science Foundation, March 10, 2000.

Prabhu, S. S., & Ramarapu, N. K. (1994). A prototype database to monitor course effectiveness: A TQM approach. *T.H.E. Journal*, *22*(3), 99-103.

Ratay, G. M. (1992). Success with lean and lively calculus. *Focus on Calculus, 1*, 4.

Ratcliff, J. L. (1994). What we can learn from coursework patterns about improving the undergraduate curriculum. In J. S. Stark & A. Thomas (Eds.), *Assessment & program evaluation* (pp. 567-579). Needham Heights, MA: Simon & Schuster ASHE Reader Series.

Ratcliff, J. L., & Jones, E. A. (1993). Coursework cluster analysis. In T. W. Banta and Associates (Eds.), *Making a difference: Outcomes of a decade of assessment in higher education* (pp. 256-268). San Francisco, CA: Jossey-Bass.

Seltzer, S., Hilbert, S., Maceli, J., Robinson, E., & Schwartz, D. (1996). An active approach to calculus. *New Directions for Teaching and Learning, 68*, 83-90.

SUCCEED Project. (1996). *Manual for curriculum innovation and renewal.* Gainesville, FL: College of Engineering, The University of Florida.

Tidmore, E. (1994). Comparison of calculus materials used at Baylor University. *Focus on Calculus, 7*, 5-6.

Tobias, S. (1990). Stemming the science shortfall at college. In S. Tobias (Ed.), *They're not dumb, they're different* (pp. 7-18). Tucson, AZ: Research Corporation.

Tobias, S. (1992). Science education reform: What's wrong with the process? In S. Tobias (Ed.), *Revitalizing undergraduate science: Why some things work and most don't* (pp. 11-22). Tucson, AZ: Research Corporation.

Twigg, C. A. (1999). *Improving learning & reducing costs: Redesigning large-enrollment courses.* Troy, NY: Center for Academic Transformation, Rensselaer Polytechnic Institute.

Van Valkenburg, M. (1990). Second option: Turning off students: Our gatekeeper courses. *Engineering Education, 80*(6), 620.

Willemsen, E. W. (1995). So what is the problem? Difficulties at the gate. *New Directions in Teaching and Learning, 61*, 15-22.

Wilson, R. (1997). A decade of teaching "reform calculus" has been a disaster, critics charge. *Chronicle of Higher Education, 43*:22, A12-A13.

Woods, D. R. (1996). Problem-based learning for large classes in chemical engineering. *New Directions for Teaching and Learning, 68*, 91-99.

Web Site Resources

CIERP Projects: ICE[2] 2005, The University of Texas at El Paso. Retrieved June 21, 2006, from http://irp.utep.edu/

SOS Math, The University of Texas at El Paso. Retrieved June 21, 2006, from http://www.sosmath.com/

UTEP Modular Precalculus. Retrieved June 21, 2006, from http://www.math.utep.edu/classes/precalculus/home.html

UTEP Modular Calculus. Retrieved June 21, 2006, from http://www.math.utep.edu/classes/calculus/

CHAPTER 11
THREE REFORM INITIATIVES: RESTRUCTURING ENTRY-LEVEL COURSES

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Introduction

The University of Arizona mathematics entry-level program was created in fall 1985 in response to the findings of a 1984 report of a Provost-appointed university committee on freshman mathematics. There were two main concerns: the high drop/failure rates and the low level of student achievement. This resulted in new resources allocated to the Mathematics Department to address the problems identified by the committee. The department embarked on an improvement plan to reform the curriculum, guided by extensive assessment and appraisal strategies. In this report we describe the activities and results on three initiatives that were components of this plan: the algebra program, the calculus program, and the mathematics for business program. We also discuss future assessment directions under the auspices of the Provost's Office that will help set the direction of the Mathematics Department for the next twenty years. Other information about reforming mathematics courses at the University of Arizona is available in earlier publications (Ewing, 1999, pp. 113-122; Lomen & Toubassi, 1994; Toubassi, 1991).

Background

During the 1970s, enrollment in University of Arizona entry-level mathematics courses (Intermediate and College Algebra, Trigonometry, Finite Mathematics, Business Calculus and Calculus I) increased significantly. Indeed, from 1969 to 1976 the enrollment in these courses increased by 67% from 6,538 to 10,915. During this same period the number of tenure-track faculty positions in mathematics decreased. The resulting strain on resources forced the Mathematics Department to make some difficult choices in order to meet its teaching obligations, the two most drastic being:

1. Thousands of students in Intermediate and College Algebra went into a self-study learning program, and
2. Thousands more students in Finite Mathematics and Business Calculus were taught in lectures of up to 600 students.

These moves resulted in a depersonalized form of learning that frustrated students and faculty alike. The attrition rates, drops plus failures, were very high, and in some cases over 50%. For a dozen years, resources to change this situation were not available to the department.

The first sign of change appeared in 1983 when the provost appointed a University-wide committee to look into freshman mathematics. The nine-member committee consisted of the Dean of the Faculty of Science and faculty members from mathematics, engineering, business and social sciences. Data collected by this committee illustrated the poor state of many lower level mathematics courses and the resulting negative impact on both students and other units of the university. In its report (Provost Committee, 1984) a year later, the committee made a variety of recommendations along with the statement: “Although other factors need to be considered, it is difficult to avoid the conclusion that many of the problems in freshman math can be traced to inadequate allocation of resources by the University Administration.”

Other Committee recommendations included:

- Hiring a pool of qualified teachers to augment the regular mathematics faculty;
- Creating a program for freshman mathematics;
- Supporting an outreach program for pre-college students;
- Creating a student database with test scores and high school data; and
- Implementing a mandatory mathematics placement program.

In the end, the study was well worth the effort it entailed. The University administration was convinced that major change was necessary, and they presented a Mathematics Decision Package (University of Arizona, 1984) to the State Legislature asking for a major funding increase to support improvement of the entry-level mathematics courses at the university. The Decision Package and subsequent allocations provided funds to hire 3 regular faculty, 2 visiting faculty, 10 teaching assistants, 20 instructors, and a full-time secretary; the purchase of 20 computers to provide a homework laboratory for algebra students; support for a mathematics readiness testing coordinator; a budget for student wages for paper graders; and a small travel budget.

In response the Mathematics Department drew up a five-year plan for 1985-1990. This plan included:

1. Replacing the self-study algebra program and all large lecture courses with small classes of about 35 students each. In order to carry this out, the university committed to hiring a core of instructors with full-time appointments and continuing status to specialize in teaching entry-level mathematics courses.

2. Instituting a mandatory mathematics placement test to ensure that students are placed in courses commensurate with their abilities and mathematical background.
3. Introducing a first calculus course of five-semester-credit hours in addition to the three-credit course already in place. This was based in part on a department self-study and the results of a survey that showed that the average calculus sequence at peer universities was 12.6 semester credit hours compared to Arizona's 10.

Moreover, the department concluded that successful implementation of the plan required two additional ingredients: increasing university admission requirements in mathematics and developing bridges to local schools and community colleges. The first was accomplished in two stages when the university increased the admission requirements in mathematics from two to three years of high school mathematics in 1988 and to four years in 1998. The second resulted in the creation of the University-School Cooperative Program whereby school teachers spend a year on campus, fully paid by their districts, to teach and take courses, and to participate in a mathematics instruction colloquium. In return, the university sends replacement teachers to the districts to cover the participants' classes. In addition, with support from the National Science Foundation (NSF), the department faculty led many summer workshops for K-12 teachers. Department accountability increased because of the additional resources that resulted from the Decision Package funds. This required the department to continue to document the success of the reforms and to defend the integrity of the new instructor positions. The data collected in the self-study and new information tallied after the reforms were critical in justifying the changes and additional resources (Arizona Mathematics Department, 1985). The old data were vivid reminders of how bad things had been, the new data illustrated how much better things had become, and so the reforms stood.

The data in the report of the 1983 provost-appointed university committee was considered as a benchmark for future studies. The first follow-up evaluation took place in 1990 and centered on two measures identified by the provost committee:

1. Pass rates (percent of grades A, B, C, or D) in entry-level courses, and
2. Grade point average (GPA) of all grades earned in the entry-level courses.

Table 1 below compares the overall pass rates and GPA for six or more consecutive semesters of entry-level courses under the new format (new sections) and the same data for the pre-reform sections (pre-EL). The enrollment in these courses is very large. For example, in fall 1986,

Table 1
Comparison of Pass Rates and GPA of New Sections with Pre-EL Sections

Course	Teaching Format	A-D	GPA
Math 116	82-85 (6 semesters) pre-EL	44%	1.26
Intro to Coll. Alg.	86-89 (7 semesters) new sections	74%	2.21
Math 117	82-85 (6 semesters) pre-EL	56%	1.74
College Algebra	85-89 (9 semesters) new sections	76%	2.32
Math 119	82-85 (6 semesters) pre-EL	63%	1.73
Finite Math	86-89 (7 semesters) new sections	78%	2.39
Math 124/125A *	82-85 (6 semesters) pre-EL	47%	1.91
Calculus I	86-89 (7 semesters) new sections	72%	2.38

Note: The course numbering was changed in the 1990s

Introduction to College Algebra had an enrollment of 1,345 students, College Algebra had 1,927, Finite Mathematics 673, and Calculus I 1,006.

The events and the work that followed for the next fifteen years has had profound effects on the Mathematics Department; most effects were positive, some arguably negative. One major change, however, was a lasting understanding of the power of continuing careful assessment. Over the past 20 years the Mathematics Department at Arizona has measured its successes—and its failures—through a collection of assessments and appraisal strategies. Below, we focus on three initiatives that illustrate these strategies and model the results: initiatives in entry-level algebra, calculus reform, and mathematics for business.

Attention to Algebra Courses

As at any large state university, entry-level mathematics courses at Arizona serve a wide range of diverse needs. The university has a general education mathematics graduation requirement for all students, and for some students, algebra is, by default, the terminal mathematics course. Other students need a college algebra course that prepares them for additional required technical courses. Some colleges and majors need students with algebra skills sufficient for their own specialized quantitative courses; others depend on the Mathematics Department to teach elementary statistics and probability to their students. The Business College has always had a two-semester mathematics sequence required of their majors. Of course, science and engineering majors need to take two, three or more calculus courses. Entry-level freshman mathematics courses must focus on all these diverse needs and yet remain flexible enough to accommodate students with changing career goals.

From the outset of this reform effort, the Mathematics Department has carefully scrutinized its algebra courses. In implementing the changes under the Decision Package discussed above, the department eliminated the self-study program and replaced it by small sections with about 35 students each. To help maintain standards and coordinate syllabi, all sections were organized around common schedules, common testing and grading regimens, and common final examinations. Comparable structures were designed for other large, multi-section courses such as the business sequence and calculus. With such a strong structure in a few large courses, the department could easily collect and study information about student and instructor performance. Originally, this was used to document the improvements in student performance under the Decision Package, but, in time, data like student examination grades were used to help set the course syllabus, choose the test, and eventually design other courses.

The department offered a course titled Intermediate Algebra until 1998. It was eliminated when the admission requirements of four years of high school mathematics took effect. To make up for the lost intermediate algebra course, one unit was added to the College Algebra course. The chief argument for making this change was built on the extensive data the department had from its mathematics placement test, common examination scores, and final grades in both Intermediate and College Algebra. A few years later in 2002, the department reintroduced a three-credit College Algebra course as an alternative for better prepared students. Again, the placement criteria and course syllabus were set after a careful study of the students in College Algebra.

Intermediate Algebra was replaced with a new general education mathematics course for students who did not need specific algebra skills for later coursework. Nevertheless, most entering freshmen continued to satisfy the general education requirement with College Algebra because of its role as a prerequisite around the university.

Calculus Reform

The Arizona Mathematics Department was greatly involved in the calculus reform movement of the early 1990s. Arizona was one of the first to join the NSF-funded consortium of schools led by Harvard University that developed a plan to restructure the calculus curriculum. The Harvard consortium would become perhaps the most successful of the NSF-funded calculus projects of that era. Arizona classrooms tested the earliest material written by the consortium; it field-tested the first textbook manuscripts, and it adopted the first published edition of the consortium-produced textbook for one of two calculus sequences for science and engineering students.

The changes in calculus teaching and syllabus introduced during this time were controversial, both nationally and within the department itself. There was a strong effort in the department to carefully examine the reform efforts in a professional and collegial manner. In two attempts in the 1990s to quantify any difference between reform and traditional curricula, the department ran parallel tracks of Calculus I and Calculus II. Students' grades were monitored in calculus and in subsequent technical courses. As it turned out, it was not possible then to make a fair comparison of the two approaches even from the extensive data collected during these periods. University registration allowed students to choose their calculus track, especially in Calculus II, so students were not distributed randomly. Neither were the instructors assigned randomly. As one might expect, the greatest factor in a student's grade in calculus and other technical courses is the student. Students' calculus instructors also have strong influences on students' grades in calculus and later courses. Even with a large number of students' records, it was virtually impossible to control these influences to distinguish between calculus textbooks and styles of exposition. By the later 1990s the department had made a commitment to a reform approach to calculus instruction, and, in particular, to the textbook produced by the Harvard consortium (Hughes Hallett *et al*., 2005).

Arizona and six other institutions participated in a recent evaluation study of calculus reform funded by NSF (Ganter & Bookman, 2004). At Arizona, students who took Calculus I in fall 1990 were compared with those entering in 1998. The latter students were tracked through 2002. Below are some of the conclusions of the Arizona component of the study.

- Even though the mean GPA of the calculus sequences have decreased, the percent of students getting A-Cs is about the same or better. The lower mean can be explained by the fact that a higher percent of students are not withdrawing from the course and, therefore, receiving failing grades. The way calculus is being taught has not affected the percent of successes or failure in the courses beyond Calculus I.

- There is a significant change in the average GPA of engineering courses taken by the later students that might be attributed to the way calculus is taught. Students did comment on how well they felt they were prepared for their engineering courses, and that the engineering courses were easier than the mathematics courses.

- Students were confident in their ability to do mathematics problems. It was important to them to emphasize their confidence in their particular field of study. They also believed they have a very firm handle on computational skills. Many stated that they usually try to do their engineering problems by hand and then check them with a software program or calculator.

- Students feel their mathematics courses prepare them well for their science and engineering courses and for their careers outside of college.

Mathematics for Business

In 1998 a member of the Mathematics Department faculty and a professor from the Finance Department began a collaboration that would result in a new sequence of mathematics courses for undergraduate business majors (Lamoureux & Thompson, 2003, 2005). The new courses replaced the standard Business Calculus and Finite Mathematics courses with an integrated program built on specific business decision projects. In keeping with the structure of other courses in the Business College, the courses emphasized a group approach to problem solving. Topics from calculus and finite mathematics were introduced in the context of answering questions about specific business models. The courses combined algebraic and analytic techniques with the computing power of business spreadsheets. Student groups explain the solutions to the problems using presentation software, justifying their conclusions using the typical computer tools of business. Still, the courses required individual students to have a firm understanding of the underlying mathematics. The new courses replaced the two courses in calculus and finite mathematics in 2002.

The new courses are a hybrid of business and mathematics, both in subject matter and pedagogy. The courses are taught by Mathematics Department instructors who need training in the terms and ideas of the business applications on which the course is built. Further, the group work aspect of the class requires a different grading paradigm that must be balanced with the measurement of individual accomplishment. The department monitors student grades and common examination scores to help instructors set equitable standards in the new course.

In Table 2, the data in Table 1 are updated for the most recent seven semesters, fall 2001 to fall 2004, and include the pass rates and GPAs for the two new business courses. The first course, called General Education, replaced the Intermediate Algebra course, listed as Introduction to College Algebra in Table 1. The others, College Algebra and Calculus I, are the new courses in Table 1. The number of students in these courses is large. For the fall 2004 semester the enrollment in the courses listed in Table 2 was as follows: 177 in Math 105; 1687 in Math 110; 282 in Math 115A; 464 in Math

115B; 718 in Math 124; and 209 in Math 125. Except for Math 105, the data in Table 2 reflect thousands of students in each course. All these courses are taught in small lectures with 28 to 35 students each.

Looking at Tables 1 and 2 one can see that the results are generally positive. Each of the courses in Table 2 has higher pass rates and average GPAs when compared with the pre-entry level years 82-85 found in Table 1. In some cases the numbers are significantly higher. When the data in Table 2 are compared with the data in the piloted sections at the start of the entry level program in years 86-89, the results are somewhat mixed. In some cases they are better, and in other cases they are not. This is understandable, because new reform activities tend to generate a lot of energy and enthusiasm on everyone's part. We hope to build on our success with the new curriculum study that is about to get underway (see section New Study and the Future below).

Table 2
Pass Rates and GPA for Reformed Classes 2001-2004

Course	A-D	GPA
Math 105 (General Education)	81%	2.38
Math 110 (1 semester, 4 credit College Algebra)	76%	1.83
Math 115A (1st semester of new Business Math)	89%	2.48
Math 115B (2nd semester of new Business Math)	91%	2.71
Math 124/125* (Calculus I)	70%	2.00

**Note: Math 125 is the new number for Math 125A.*

Other Curriculum Changes

We have outlined three large initiatives undertaken by the Arizona Mathematics Department. There have been many other courses and course sequences that have undergone curriculum changes. The mathematics course for elementary education majors has been revamped and expanded to two semesters, and the training program for secondary teachers continues to be refined and adjusted. The department offers undergraduate mathematics majors several options in degree programs to better fit an individual's course work with his or her career plans. The new business course has prompted the department to look at an algebra course aimed directly towards this course. The department is currently one of 11 schools participating in an NSF-funded project sponsored by the Mathematical Association of America to test a modeling approach to college algebra.

The department's continuing refinement of its curriculum has had one increasingly noticeable negative effect. By addressing courses one at a time, the overall undergraduate program has lost some focus. It has been years since the department and the university have looked at the mathematics curriculum as a whole. University general education requirements have evolved; college degree programs have changed; departmental majors have added additional mathematics courses to their program. The success of the carefully directed business mathematics sequence has led to other requests for mathematics courses directed toward specific fields of study. At the same time, more and more majors are looking at existing courses in calculus, discrete mathematics, and probability and statistics for important general training.

New Study and the Future

At the Mathematics Department's request, the university's provost will appoint a blue ribbon panel from across the university to look at the mathematics program as a whole. The committee will include representatives from the faculty, administration, and important service units like advising and the Registrar's office. The committee will consider the undergraduate mathematics curriculum in its entirety. The department has agreed that every aspect of its current program is open for discussion, based on the belief that the study will reemphasize the central role mathematics plays in the university. The committee will, no doubt, shed greater light on the diverse responsibilities the department has as it deals with the special needs of students in degree programs throughout the university. The findings of this committee will help set the direction of the Mathematics Department for the next twenty years as the 1983 study did for the past twenty.

The Arizona Mathematics Department has met the many challenges placed before it through careful study and prudent planning. The department has developed an expectation of ongoing assessment of every aspect of its activities to make decisions based on evidence of student learning. As a result, the department has the confidence to make curricular decisions when necessary, to ask for assistance when it needs it, and to work with the rest of the university to better meet the educational needs of its students.

References

Arizona Mathematics Department. (1985). Self-study of the entry-level program. Tucson, AZ: University of Arizona.

Ewing, J. (Ed.). (1999). *Towards excellence: leading a doctoral mathematics department in the 21st century*. Providence, RI: American Mathematical Society.

Ganter, S., & Bookman, J. (2004). The impact of calculus reform on long-term student performance. Unpublished report to National Science Foundation on grant #9912017. Clemson, SC: Clemson University.

Hughes H. D., Gleason, A., Lomen, D., Lovelock, D., McCallum, W., Tucker, T., et al. (2005). *Calculus, single variable (4th ed.).* Hoboken, NJ: John Wiley and Sons.

Lamoureux, C., & Thompson, R. (2003). *Mathematics for business decisions*, Part 2, Release 1.0. Washington, DC: Mathematical Association of America.

Lamoureux, C., & Thompson, R. (2005). *Mathematics for business decisions*, Part 1, Standard Edition Release 1.5 and Alternative Edition Release 1.5a. Washington, DC: Mathematical Association of America.

Lomen, D., & Toubassi, E. (1994, July). A case study in systemic change, *UME Trends 6*(3), 12-15.

Provost Committee. (1984). An analysis of freshmen mathematics courses. Unpublished report. Tucson, AZ: University of Arizona.

Toubassi, E. (1991). A report on an entry-level math program. In N. D. Fisher, H. B. Keynes, & P. D. Wagreich (Eds.), *Mathematicians and education reform* (pp. 97-112). Washington, DC: Conference Board for the Mathematical Sciences.

University of Arizona. (1984). Request to Arizona Legislature for funding increase for mathematics. Tucson, AZ: Author.

CHAPTER 12
ASSESSMENT: THE BURDEN OF A NAME[1]

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Introduction

A ballad by Johnny Cash, “A Boy Named Sue,” chronicles a boy’s growing up and the hardships that ensued because of his name. Fighting in bars and taverns and withstanding the insults of detractors seemingly give the boy character and strength as he becomes a man. However, the ballad ends with the main character’s avowal to name his own son “anything but Sue!” An analogous ballad might someday be written about assessment.

Thrust onto the U.S. higher education scene in the final two decades of the twentieth century, assessment continues to suffer mightily from misunderstanding, much of it because of the burden of its name with its multiple meanings and interpretations (Ewell, 2002). The other weighty contributor to this misunderstanding is assessment’s cadre of early promoters —administrators, governing boards, accrediting agencies, and legislatures. Most college faculty believed that assessment was, as the name implied, only some kind of comprehensive evaluation. They knew, as did every farmer, that weighing one’s produce did not hasten its readiness for market. They also knew that the motivations of the promoters of assessment were anchored in evaluation and accountability. So the lines were drawn, and assessment has struggled against these misunderstandings to gain both respectability and usefulness in US higher education.

Struggling with the Name

Efforts have been made to modify the assessment rubric to better convey meanings and purposes. We distinguished between summative assessment and formative assessment to try to clarify why assessment is done. We resorted to assessment cycles to imply that assessment was a continuous process rather than a discrete event. We added prepositional phrases to clarify the purpose when we talked of assessment of student learning and assessment in the service of learning. We tried to distinguish kinds of assessment by referring to classroom assessment, large-scale assessment, authentic assessment, and alternative assessment. Grant Wiggins authored a book with a title that attempts to delineate the purpose of assessment, *Educative Assessment* (1998). But the noun, and hence the center of attention, is assessment, and this word continues to convey misleading meanings and images in spite of modifying word or phrases. Choosing another noun will probably not help, though name changes are the order of the day in the “dot.com” world. Sometimes, non-meaning is the key in these new name searches, as many of us remember—for crossword puzzles, if nothing else—the search for Exxon to replace Esso. A nonsense rubric might be the solution for assessment, but my thesis here is that we already know what assessment should be and really is, and we just need to acknowledge that. In these few pages I will elaborate on this thesis.

Some History

Comprehensive assessment of individual student learning in an entire academic program is not new to U.S. higher education. In the early years, end-of-program examinations, some using external examiners, were the norm for college degrees. Expanding enrollments of the twentieth century made large-scale assessment of learning in academic programs less practical. Consequently, most assessment of student learning was bound up in course grades, mainly using what we now call classroom summative assessment. Most course grades depended on a one-dimensional evaluation process—periodic in-class examinations—and some comprehensive final examinations over individual courses. Many of the current collegiate faculty grew up with this assessment scheme and found it reasonably satisfactory, so there was no groundswell for change from that faculty. Yet, through use in some academic programs, that faculty acknowledged the value of comprehensive formative assessment using multi-dimensional measures of learning. The programs that attracted such assessment most often were the terminal graduate degree programs, typically the doctoral programs.

Assessment Under Other Guises

Consider how doctoral students and new doctorates are assessed, both for individual learning and for program evaluation and improvement. Many times, course grades are not the determining factor; most grades are As with a few Bs. Doctoral students are judged by their participation in seminars where they listen, discuss, and present. They are almost constantly in conversations with graduate faculty and potential thesis directors, being judged on how well they understand and being coached in areas where they need help. They are tested by faculty committees, in presentations ranging from thesis design to oral examinations. They sit for written examinations over a range of courses and subject areas. Eventually they participate in a significant capstone experience, writing and defending a dissertation. The assessment of achievement of doctoral students continues beyond the doctoral degree, to their employment successes (e.g., achieving tenure) and their publishing records. Most discipline faculties have no doubt about the quality of their doctorates; there are elaborate assessment processes that tell them. And with each doctoral student, the process of educating new doctoral students may be refined and improved. Thus the assessment can be formative, or an assessment cycle. Perhaps this is one reason why U.S. graduate education is indisputably the best in the world.

So, if discipline faculties use these comprehensive schemes for their doctoral students, why not use analogs for their undergraduates to assess their learning in general education or study in depth? The major reason is that undergraduate students far outnumber doctoral students, and assessment of student learning of a sample of the students for the purpose of program improvements has not been widely adopted. Yet, most faculty do practice formative assessment, albeit unknowingly and casually, in their classrooms. Even in the outmoded and discredited lecture method that most of us still use, formative assessment is often very much present. As we lecture, we survey faces, looking for signs of understanding or puzzlement, and we adjust accordingly. Some of us sprinkle our lectures with generic questions such as “Do you see?” or “Is that clear?” I can remember professors of mine who inserted such a question randomly and frequently, to the point that counting the number of occurrences of the question in the lecture became an amusement. Often times, though, these questions represented a subliminal obligation, and were not asked to elicit an answer. They were, however, recognition that a part of teaching is gauging understanding and responding with changes in instructional methods. Perceived lack of time prevented a more substantial judgment of learning and more substantial analyses of how learning could be improved. And, of course, we were dealing with only one course, limiting our assessment accordingly. Furthermore, we knew, if we really thought about it, that feedback from expressions or head nodding were unreliable. Students, too, developed habits of behavior like my professors who reflexively asked, “Do you see?”

Responses to the Assessment Movement

Even though collegiate faculty through their actions showed strong belief in assessment—even formative assessment—the way assessment came to most faculties created resistance, or, at best, ritualistic compliance. Some faculties at some schools, Alverno College, for example (Alverno, 1979), had adopted assessment as an integral part of their instructional program and were thriving. Yet most models of assessment seemed not to adapt to larger, more diverse institutions, so many administrations tried to build assessment from the top down, or bottom up, depending on how you view the hierarchy in higher education institutions. Some created, for goodness sake, vice presidents for assessment, giving it status parallel to fund-raising, computing technology, and fiscal affairs. This added fuel to the faculty belief that assessment belonged to others, and that it was an unnecessary waste of resources.

The assessment movement swept aside this faculty reluctance, and assessment programs for varying and often misunderstood purposes were mandated by governing boards, legislatures, and accrediting agencies. The

American Association of Higher Education (AAHE) began holding annual Assessment Forums. I attended several of those in the early 1990s to try to learn about assessment. I had been appointed Chair of the Subcommittee on Assessment of the Committee on the Undergraduate Program in Mathematics (CUPM) of the Mathematical Association of America (MAA), and we were charged to advise MAA on assessment. Eventually, we did write guidelines (CUPM, 1995/1999) for mathematics departments to follow in setting up an assessment cycle for the purpose of program improvements, and hence more student learning. We explained how one should set learning goals, devise and implement instructional strategies, measure learning, and then start all over again, using what had been learned from the experience of previous cycles. We were getting closer to the true meaning of assessment, but we were not there yet. Our assessment cycles were still described as add-ons to instructional programs.

My AAHE Forum Experiences

My experience at the AAHE Assessment Forums helped greatly with my understanding of assessment. Some of the presentations amazed me - among the most amazing were the ones giving curricula on assessment in higher education graduate programs. I saw little involvement by the disciplinary faculties. What I saw was a huge cottage industry on assessment being formed and thriving external to the very core activity to which it was presumably directed, teaching and learning in colleges. I was struck by the repetition in the presentations, and, at the same time, puzzled by seemingly different meanings of assessment. I was struck by my familiarity with many of the ideas in assessment programs and the techniques, too. I was struck by the use of language - words took on meanings different from how they were understood in my discipline of mathematics. The plenary speakers were inspiring, articulate, and memorable, clearly having thought deeply about something I believed I had just discovered, but also being very knowledgeable about higher education. The whole experience was perplexing, but I wasn't sure why. I had not yet mapped the assessment they were talking about onto my experience.

What Assessment Really Is—Or Ought To Be

I slowly began to realize that I had met assessment before, many times, but under different rubrics. Assessment was really a part of teaching and learning. It was just probing further along the lines of my professor's "Do you see?" It was finding complex answers to that question and going further to find ways to increase understanding. It was not something foreign or external to the teaching and learning process; it was an integral part. Therefore, its name was misleading, and the way of imposing it from outside the teaching and learning process was at best misguided.

Assessment is neither new nor exotic. It is and has been a part of every faculty member's work. All that is new is going beyond one class and one professor to ask that question "Do you see?" over a broader range of material and probing further to find how learning can be improved. So why do we need another word—one that conjures up visions of tax bills—to describe a part of teaching? Assessment should be done to enhance teaching, increase learning, and improve programs because it is a part of those processes. Its identification as something external to the process of teaching and learning has greatly hindered implementing the new and productive ideas of the assessment movement. So, let's think of a better name and a better way to have disciplinary faculties claim ownership of something that is already theirs. Perhaps a name that suggests this would be helpful, such as responsive teaching. As the Johnny Cash ballad ends, "anything but assessment!"

Endnote

1 This essay was written for the 2002 PKAL Roundtable on the Future, Assessment in the Service of Student Learning. See http://www.pkal.org/documents/AssessmentTheBurdenOfAName.cfm

References

Alverno College Faculty. (1979). *Assessments at Alverno College*. Milwaukee, WI: Alverno Publications.

Committee on the Undergraduate Program in Mathematics (CUPM). (1995/1999). Assessment of student learning for improving the undergraduate major in mathematics. *FOCUS: The Newsletter of the Mathematical Association of America, 15*(3), 24-28. Reprinted in B. Gold, S. Keith, & W. Marion (Eds.), *Assessment practices in undergraduate mathematics* (pp. 279-284). Washington, DC: Mathematical Association of America.

Ewell, P. T. (2002). An emerging scholarship: A brief history of assessment. In T. W. Banta & Associates (Eds.), *Building a scholarship of assessment* (pp. 3-25). San Francisco, CA: Jossey-Bass.

Wiggins, G. P. (1998). *Educative assessment*. San Francisco, CA: Jossey-Bass.

The *Assessment in the Disciplines* volumes have been designed to provide assistance to both faculty who have taken on responsibility for assessing their academic programs, as well as institutional researchers who are often asked to support student learning assessment activities across their campuses. We hope that the discussions presented in this series will contribute to the development of assessment strategies that will result in improved student learning on our college and university campuses.

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