MATHEMATICS PLACEMENT AND ASSESSMENT AT CENTRAL MISSOURI STATE UNIVERSITY

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For the past decade, a wide range of issues in U.S. education have been the subject of intense scrutiny and introspection from government agencies, legislatures and professional organizations. The mathematical sciences have received a "fair share" of this attention. The Mathematical Association of America, the National Council of Teachers of Mathematics, the American Mathematical Society, the National Research Council and several other organizations and joint boards and committees have produced dozens of documents that express concerns and make recommendations about such issues as the funding levels of mathematical research, the relevance of current mathematics curriculum at all levels, the effectiveness of certain methods of instruction and the mathematical preparation of teachers.

As a result, the re-evaluation and assessment of courses, majors and programs have become common agenda items for mathematical sciences departments at virtually every college and university in the country. Since the fall of 1986, the Department of Mathematics and Computer Science at Central Missouri State University has been studying, implementing and refining several assessment projects and procedures. The task has been both rewarding and frustrating and the results and benefits have been both encouraging and disappointing. It is the intent of this article to report on our department's assessment activities of the past six years. While our efforts are far from complete, the sharing of this information may stimulate some dialogue which will be mutually beneficial.

Institutional Background

A short description of Central Missouri State University and the Department of Mathematics and Computer Science may provide a useful perspective from which comparisons can be made. Central is a regional, state-supported, comprehensive institution located in Warrensburg, a community of approximately 15,000 some 50 miles southeast of Kansas City. In the fall of 1991 about 11,600 students were enrolled (10,100 undergraduates and 1,500 graduates). The academic departments are organized into four colleges: Applied Sciences and Technology, Arts and Sciences, Business and Economics, and Education and Human Services. In addition the university supports a School of Graduate Studies and Research. Most departments have masters degree programs and a few offer specialists degrees. Criteria for admission to Central is liberal, approaching open-admission.

In 1991 the Department of Mathematics and Computer Science had 24 full-time faculty and 10 graduate assistants. At the undergraduate level the department offers majors in

Mathematics **(20)**, Computer Science **(80)**, Actuarial Science **(50)** and Secondary Mathematics Education **(50)**. **(The figures in parentheses indicate the approximate number of majors in the programs in the 1991–92 academic year).** The Mathematics Education faculty is responsible for a two-course, eight-hour sequence taken by Elementary Education majors as well as for a Math Minor program **(90)** which extends certification for Elementary Education majors to teach mathematics in grades 4–9. An MS degree in Mathematics **(25)** is offered as well as an MSE program **(10)** which is jointly advised with the Department of Curriculum and Instruction.

The department has a major service responsibility to the university, particularly with its role in the General Education Program. All students are required to complete a mathematics course from a prescribed list which includes College Algebra, Pre-Calculus Mathematics and Calculus I. We also offer a three-hour Business Calculus course which is a requirement for admission into programs in the College of Business and Economics.

Placement

At our university Mathematics and Computer Science was one of the first departments to initiate formal assessment activities. Our administration, anticipating a state-level mandate to establish an assessment plan, felt there might be fewer complications with mathematics than with most other disciplines and that reportable results might be obtained more quickly. The task has been much more involved than expected.

The first issue addressed by the department was that of placement. Prior to 1986, the department administered a 40-question department-generated placement test in sections of College Algebra during the first class period of the semester. The results were used to advise students to remain in College Algebra or to transfer, usually to a lower level course. However, our university has no mandatory placement policy. Students tended to underestimate the difficulty of the College Algebra, overestimate their abilities and determination, and in general did not want to trouble themselves with changing their schedules. As a result most students who were advised to transfer out of College Algebra decided to remain. Unfortunately most of these students earned a D or an F or withdrew from the course. The department felt that if a placement test could be given to students prior to enrollment we would stand a better chance of placing them in a mathematics course which better matches their backgrounds and current abilities.

In 1986 the department proposed that a mathematics placement test be administered to entering freshmen during the two-day summer orientation-registration sessions. This process began in the summer of 1987.

The Mathematical Association of America Placement Test Program was selected. During the first two years, 1987 and 1988, the department experimented with combinations of the MAA Algebra test (with questions ranging from the basic to the advanced), the MAA Advanced Algebra test and a 15-question supplement generated by our department.

For the majority of students entering our university, scores earned on the MAA Advanced Algebra test provided insufficient diagnostic information. A low score on this test

merely indicates that the student is not ready for College Algebra but gives no assistance in determining whether to place the student in Introductory Algebra or Intermediate Algebra. Also the department supplement was found to do little to refine the placement process. Thus, since 1989 all entering freshmen who enroll during the summer are given the 32-question MAA Algebra test (basic and advanced combined).

Placement Procedures

Students who are scheduled to attend one of the orientation-registration sessions are informed by letter that they will be given a mathematics placement test during their two-day visit to the campus. They also receive a sheet of sample test questions.

On the first day of orientation, following an opening introductory assembly, the test is administered. The academic advisors have the results later that afternoon in time for their sessions with the students.

Entering freshmen who do not participate in orientation-registration sessions are given the placement test on an individual basis during July and early August.

The following test scores and high school backgrounds serve as guidelines for placement:

Recommended Course	Test Score MAA Algebra Test	High School Background Required
Introductory Algebra	0 – 9	no high school algebra
Intermediate Algebra	10 – 16	one unit of algebra
College Algebra	17 – 32	two units of algebra including advanced algebra.

Placement is not based solely on the performance of the MAA Algebra Test. Other factors that academic advisors consider in deciding which mathematics course to recommend, particularly for courses more advanced than College Algebra, include the high school percentile rank, the ACT composite score and the ACT mathematics subscore. While any placement procedure has cases in a "gray area," the more factors that agree, the more confidence we have in our recommendation. In general, the placement test is the single most influencing factor.

Placement Results

The mean scores for all students who have taken the 32-question placement test for the past three years follow:

Year	No. of Students	Mean
1989	2266	11.565
1990	1938	12.026
1991	1900	12.561

An item analysis of test questions shows that entering freshmen generally are weak in the areas of logarithms, fractional equations, absolute value, linear systems, and quadratic inequalities.

Placement primarily focuses on algebra. Thus the remaining discussion concerning placement results is restricted to entering freshmen who took the placement test in the summer **AND** enrolled in a section of Introductory Algebra, Intermediate Algebra or College Algebra the following fall semester.

Even without a mandatory placement policy, the academic advisors report that most students who take the placement test accept the mathematics course which is recommended. The following table for 1991 compares the students' test scores with the courses chosen for enrollment.

Score	Introductory Algebra	Intermediate Algebra	College Algebra
0 – 9	286	90	7
10 – 16	24	257	81
17 – 32	1	18	267

The next table lists the success rates of students who were placed in a course according to the recommended scores listed above. Success means that a student earns an A, B or C in the course. Withdrawals are not included in the studies because factors unrelated to the course and a student's preparation for the course can cause a student to drop a class.

Recommended Score	Introductory Algebra 0 – 9	Intermediate Algebra 10 – 16	College Algebra 17 – 32
Success Rates			
1989	59.0%	85.4%	81.6%
1990	64.3%	78.0%	78.4%
1991	66.8%	78.6%	83.4%

Pearson Correlation Coefficients have been calculated for the last three years relative to placement test scores, ACT composite scores, ACT mathematics subscores, and high school percentile ranks as predictors of final grades. The high school percentile rank generally is the strongest predictor for the final grade. The placement test score, the ACT composite score and the ACT mathematics subscore all are considered strong predictors with coefficients close in value.

Based on these studies, the department is confident that its placement process is of value to the students and the university and plans to continue the procedure in the future. While the high school percentile rank generally is the strongest predictor for a final grade, the placement test score is the most current information the academic advisors have at the time of enrollment. As stated before, the placement test score tends to be the most influencing factor in deciding which mathematics course to select.

Assessment of College Algebra

Under the university's current General Education Program, College Algebra is the mathematics course taken by most students. Thus our department decided that this course should be included in our overall assessment plan. A pre-test, post-test study has revealed some interesting trends and significant changes in the role of College Algebra over the past several years.

In the first class meeting following the drop-add period, the 25-question MAA Advanced Algebra Version 2A test is given in all sections of College Algebra. Version 2B of the test is administered during the last two weeks of the semester. The study includes a comparison of pre-test and post-test results and an analysis of gains for specific topics on the tests. Included in the following table are students who completed College Algebra and for whom complete data are available.

	Fall Semesters				Spring Semesters			
	No. of Students	Pre–Test Mean Score	Post–Test Mean Score	Gain	No. of Students	Pre–Test Mean Score	Post–Test Mean Score	Gain
1989–90	591	9.39	14.25	4.86	388	8.94	12.25	3.31
1990–91	577	9.08	12.99	3.91	469	8.73	12.10	3.37
1991–92	733	9.17	12.82	3.65	517	8.30	11.96	3.66

Student performance on the pre-test generally shows weaknesses in logarithms, rationalizing, graphing and distance, radical quadratic equations and functions. Significant improvement on the post-test is seen in the areas of logarithms, graphing and distance, and functions. Little gain is evident in rationalizing or radical quadratic equations. Questions involving algebraic fractions show little improvement and in some semesters a slight negative change occurs. Algebraic fractions is a review topic treated in the first one or two

class periods, usually before the pre-test is given. Interestingly we have found students in the spring semesters to have more difficulty with questions involving absolute value than students in the fall semesters.

The following table gives a general profile of a successful student in College Algebra. The mean values of all students who earned an A, B or C are given. Beginning with the fall of 1990, Enhanced ACT scores are given.

	Pre-Test		ACT Comp		ACT Math		HS Rank	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
1989–90	10.32	9.71	21.25	19.07	21.23	17.57	75.67	68.22
1990–91	9.78	9.35	22.79	20.66	22.33	19.87	79.24	72.34
1991–92	9.96	8.88	22.48	20.99	22.05	19.59	77.53	71.04

This information is used by the department to assess the effectiveness of our instruction in College Algebra and, indirectly, Introductory Algebra and Intermediate Algebra. In general, it appears that students who take College Algebra in the fall semester are better prepared and show greater pre-test, post-test scores and gains than students who take College Algebra in the spring.

General Education Impact

The study of College Algebra has not been without its frustrations. As the following table shows, from the fall of 1985 to the fall of 1991 the number of sections of College Algebra and the enrollment have nearly doubled while the success rates have declined.

	1985	1991
Number of College Algebra Sections	16	30
Total Enrollment	658	1141
Success Rate (1)	73%	65%

(1) The success rate (A, B or C) is based on those students who completed the course.

Although the university did experience a 32% growth during this period, from 8,800 in 1985 to 11,600 in 1991, this increase is not the only factor believed to be responsible for the magnitude of these changes. Revisions of the university's General Education mathematics requirement is considered another major factor. In 1985, many students took a liberal arts-type course titled "Mathematics for Modern Living" to satisfy this General Education requirement. In part due to discussions about the restructuring of the General Education program and the need for an assessment plan for the courses involved, Mathematics for

Modern Living received much campus-wide criticism, was recommended for deletion in 1987 and has been phased-out with the last section being taught in the spring of 1989. College Algebra now serves a much larger, diverse audience.

The impact of these changes can better be seen by including Introductory Algebra and Intermediate Algebra in the comparison along with College Algebra and Mathematics for Modern Living.

	1985		1991	
	Sections	Enrollment	Sections	Enrollment
Introductory Algebra	8	222	18	634
Intermediate Algebra	11	514	24	905
College Algebra	16	658	30	1141
Math for Mod. Living	9	409	0	0

Most students who were eligible to fulfill their General Education mathematics requirement with Mathematics for Modern Living could do so by taking the one course only. The content was broadly based and required less mathematics background than does College Algebra. Now many are finding it necessary to take Introductory Algebra and/or Intermediate Algebra before attempting College Algebra.

At the encouragement of several departments in the College of Arts and Sciences and the university's General Education Committee, the Mathematics and Computer Science department has developed a new General Education course titled "Contemporary Mathematics" which will be offered beginning with the summer session of 1993. Unlike Mathematics for Modern Living, Contemporary Mathematics carries a prerequisite of one year of high school algebra or Intermediate Algebra. Although the new course, like its predecessor, will include a broad range of topics such as probability, statistics, combinatorics, number theory, geometry, sets and logic, the algebra prerequisite will allow us to include more topics, such as an elementary introduction to linear programming, and be able to treat some topics at a greater depth.

Because of the significant changes in the role of College Algebra in the past and the anticipated impact that Contemporary Mathematics will have on our General Education program in the future, few conclusions or recommendations can be made. We anticipate that the availability of the new General Education course will help to improve the success rates in College Algebra.

"C" Policy

Some positive outgrowths have resulted from our assessment efforts. During the late 1980s while dealing with the phasing-out of Mathematics for Modern Living and the declining success rates in College Algebra, our faculty observed what they believed to be an

increasing number of students who were having difficulty completing College Algebra in one attempt. To confirm this and to get a better understanding of the magnitude of the problem, the department arranged to have Central's Computer Services prepare prerequisite searches for all classes. The instructor of a class receives a printout which lists the students on the roll along with the mathematics courses they have attempted in previous semesters at Central.

We discovered that many students attempted a course two or three times before receiving a passing grade. Some were found to have enrolled in the same course as many as six or seven times in the past. We observed a serious, widespread problem of students who were attempting a course having earned only a D in the prerequisite course. In many of these cases students found themselves locked in a series of "hopeless" efforts at a course for which they were not prepared.

The department also collected data which compares the final grade earned in a course with the grade earned in the prerequisite course. The following table, involving results from the fall 1991 semester, illustrates how the prerequisite grade — course grade comparison was organized for our Intermediate Algebra — College Algebra study.

Example

Intermediate Algebra (prerequisite) \ College Algebra (course taken)	A	*B*	C	D	F	W	Total
A	18	12	18	9	2	16	75
B	5	16	26	28	18	34	127
C	8	14	28	35	26	67	178
D	1	0	1	6	2	5	15
F	0	0	1	1	1	1	4
W	0	0	2	0	4	10	16
N/A	118	119	100	73	63	115	588
Total	150	161	176	152	116	248	1003

Figures along the main diagonal represent students who made the same letter grade in both courses. Students who improved are below the diagonal and students who dropped one or more letter grades are above the diagonal. This table is typical of results obtained from other course sequences and from other semesters.

It became clear that in order to give a student an optimum chance for success in a course, efforts should be made to make sure that he/she possesses an adequate prerequisite knowledge. The data supports our department's belief that a student who earns a D in a prerequisite course has little chance of succeeding in the following course. Thus the following

departmental policy was adopted effective with the spring 1990 semester.

A student may enroll in a course offered by the Department of Mathematics and Computer Science only if a grade of at least a "C" is earned in each of the course's prerequisites taken.

Using the prerequisite printouts, faculty are able to identify students who violate the policy. These students are notified that they will need to transfer to the prerequisite course. If they desire to petition for an exception to the policy they are required to prepare a written response which is reviewed by a department committee. If the committee denies their petition, they may appeal the decision to the department chair.

In the fall semesters of 1990 and 1991, more than 40 violations were identified and about 25 petitions were submitted. Approximately 6 exceptions were granted each semester primarily to seniors nearing graduation.

In the fall semester of 1992, less than 15 violations were noted and only 6 petitions for exceptions were submitted. The department hopes that the policy is beginning to pay positive dividends.

Assessment of the Major

Freshman placement, the assessment of College Algebra and the development and enforcement of the C policy have dominated the department's assessment efforts thus far. However, some attempts at assessing department majors and programs have begun with knowledge-based national examinations.

All BSE, Secondary Mathematics students are required by state law to take the National Teachers Exam in Mathematics. The successful passage of the Course 100 examination of the Society of Actuaries is a degree requirement for the BS, Actuarial Science and Mathematics major. Prior to the 1991–92 academic year, all graduating seniors were asked to voluntarily take the Major Field Achievement Test in Mathematics. Computer Science and Mathematics majors were asked to volunteer for the MFAT in Computer Science as well. Students were encouraged to do their best and were told that if they were satisfied with their performance the results could be included on their permanent record and/or used by faculty in letters of reference.

All major programs contain a common mathematics component; however, little collective information can be derived from the results of these several tests. Insufficient diagnostic data has been obtained since only a few students, usually less than 5, rarely more than 8, took any one of the tests. Thus, beginning with the 1991–1992 academic year, all

seniors are required to take the MFAT in Mathematics. No minimum score is required for graduation. A second exit examination is necessary for some majors.

In the spring of 1991, 16 students took the MFAT in Mathematics. Few generalizations can be made based on one year's data but the type of information provided by the Educational Testing Service may assist in the evaluation of our programs.

University Support

The university's administration has been very cooperative and supportive of our department's assessment efforts. In 1987 a budget was established which allowed our department to provide one-half release time for an Assessment Coordinator. In addition, sufficient funds have been provided for conference travel, student help, equipment and general operations.

The Office of Institutional Research and Testing has provided valuable assistance in the compilation and analysis of data. The Office of Admissions has provided personnel who assist with the summer placement test.

Directions for the Future

In the fall of 1992 the Department of Mathematics and Computer Science began to explore the possibility of participating in a campus-wide assessment project which is supported by the university and the Fund for the Improvement of Post Secondary Education (FIPSE). In the 1991–92 academic year, 10 academic departments inaugurated a multi-year, performance-based program called Continuous Process Improvement (CPI), a model for the assessment of the major. Their work has been extensive and our department could profit from their experience if we choose to participate.

Briefly CPI can be characterized as a multi-stage project which incorporates input from faculty, students, alumni and employers in the formation of both general and discipline-specific outcomes, the organization of a curriculum matrix showing how these outcomes are integrated throughout the program, and the development of assessment methods and strategies. Although the project involves a variety of disciplines, the CPI model can be individualized to meet the specific needs of a department.

The department will continue to study and review the numerous

assessment-related publications that pertain to the mathematical sciences. We look forward to reports from the MAA, particularly the work of the CUPM Subcommittee on Assessment of the Major.

When our assessment efforts began in 1986, we felt that our overall plan would be fully developed and nearly perfected by now. However, we now see that assessment is an ongoing process with the study of one issue raising questions about other issues. We do perceive many of our courses and programs to be stronger as a result of our studies. We do have a better collective profile of ourselves and the students we serve.

Hopefully this report will be of some worth to those departments dealing with similar issues. We welcome input and suggestions from departments whose experiences may provide valuable insights to us. Although the myriad of assessment activities that are being attempted may not be received enthusiastically by all, mathematical sciences departments have been forced to communicate, to be aware of issues common to us all and to work together to develop strategies and solutions. Our students, our departments, our professional organizations and our discipline as a whole will benefit from these collective efforts.