

Mathematics Assessment in the First Two Years

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Abstract. The Arapahoe Community College Mathematics Department participated in a two-year college-wide assessment effort. During both years, the Department analyzed data from a common final exam in College Algebra. In the second year, the Department linked an entrance exam to the common final exam to measure student learning during College Algebra. These efforts laid the foundation for a continuing annual assessment process with an ultimate goal of assessing all program-level student-learning outcomes at least two ways.

Background and Goals

For several years the department has used a Calculus Readiness placement test produced by the Mathematical Association of America (MAA) as a common final for College Algebra. The department curved test scores based on the performance of all students taking the test and the curved grade counted in each student's overall course grade. Beyond curving the test scores, detailed analyses of student performance and/or feedback channels for improving pedagogy at the department level did not exist. The department felt that the test could be used as a starting point for its efforts to develop a discipline-level assessment program with the goal of developing an instrument useful for improving the department's ability to address its student learning outcomes.

The department has used the MAA Basic Algebra placement test as an entrance exam in College Algebra for a retention improvement project. As another component of its assessment efforts, the department decided to link the entrance exam and the common final using Colorado State Core Transfer Program student learning outcomes to measure student learning in ability to work with mathematical formulas and word problems.

Description

The department developed a mission statement in harmony with the College Mission statement and the current direction of the College:

The mission of the Mathematics Department at Arapahoe Community College is to provide learning-centered mathematics education to students. The department offers courses for both full-time and part-time students supporting both transfer and career opportunities. The department is committed to quality learning-centered mathematics education valuing traditions and incorporating current effective pedagogical trends in the discipline, appropriate technology, and assessment of student learning.

Next, the department developed five student learning outcomes drawing heavily from *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus* [1]:

- Students will acquire the ability to read, write, listen to, and speak mathematics.
- Students will demonstrate a mastery of competencies identified by the competency-based syllabi for specific courses.
- Students will use appropriate technology to enhance their mathematical thinking and understanding and to solve mathematical problems and judge the reasonableness of their results.

- Students will engage in substantial mathematical problem solving.
- Students will acquire the ability to use multiple approaches—numerical, graphical, symbolic, and verbal—to solve mathematical problems.

Nearly all departmental courses address each of these outcomes. The wording of the second learning outcome was chosen to make use of the Colorado Community College System Core Transfer Program and Common Course Numbering System curriculum requirements. Both the Core Transfer Program and the Common Course Number System define student learning outcomes for individual courses offered by the department.

To test student performance on these learning outcomes, the Mathematics Department chose to use a Calculus Readiness placement test produced by the MAA as a common final for College Algebra. The department used the standard Calculus Readiness placement test in the 2001–02 academic year, but switched to the Calculator-Based Calculus Readiness placement test in the 2002–03 academic year because of a requirement that students have and use graphing calculators in College Algebra. The common final was given on the last day of classes and counted at least 10% of each student’s overall grade. Student performance data was collected for both the fall and spring semester.

After mapping questions to Core Transfer Program learning outcomes, the department decided to perform the following detailed analyses:

- Student performance on common final, which pointed to strengths and weaknesses in departmental pedagogy.
- Longitudinal comparisons of overall student common final performance for academic years 2001–02 and 2002–03, which indicated degree of consistency of results between semesters in an academic year and between academic years.
- Comparison of student performance on linked questions between entrance exam and common final exam as a measure of student learning in ability to work with mathematical formulas and word problems over the semester.

Student Performance on Common Final

During the fall semester 2002, 158 students took the common final exam; the overall performance is presented in Figure 1. During the spring semester 2003, 180 students took the common final exam; the overall performance is presented in Figure 2. Table 1 presents in descending rank order students’ overall performance by question for spring 2003. The third column in Table 1 specifies for each question the associated Colorado Core Transfer Program learn-

ing outcomes. Those associated with questions with correct response rates above 50% indicating areas of departmental pedagogical strengths are:

- B. Perform algebraic manipulations including working with exponents, radicals, polynomial operations, factoring and algebraic fractions.
- E. Work with formulas including formula evaluation and solving a formula for any of the variables.
- F. Read and analyze problems in the form of word problem applications and obtain solutions using equations.
- G. Solve first degree inequalities, higher degree inequalities and inequalities involving absolute value.
- H. Recognize and graph linear functions, rational functions, absolute value functions, and graph inequalities in two variables.
- I. Work with function notation and demonstrate knowledge of the meaning “function.”
- J. Demonstrate an understanding of function composition, one-to-one functions and inverse functions.
- K. Examine, evaluate and graph exponential functions.

Core Transfer Program learning outcomes associated with questions with correct response rates below 50% indicating areas of departmental pedagogical weaknesses are:

- F. Read and analyze problems in the form of word problem applications and obtain solutions using equations.
- I. Work with function notation and demonstrate knowledge of the meaning “function.”
- M. Work problems and solve equations containing exponential and logarithmic functions.
- O. Use at least two of the following techniques to solve linear and non-linear systems of the equations: substitution, addition, Gaussian elimination, Cramer’s rule.
- U. Work with series notation and sequence formulas, and counting principles.

Longitudinal Analyses

Comparison of fall and spring student performance data for the two academic years indicated no statistical difference between performance data for different semesters within an academic year.

The department changed from the Calculus Readiness placement exam to the Calculator Based Calculus Readiness placement exam prior to its 2002–3 assessment cycle. Since the exam version changed between spring 2002 and spring 2003, Colorado Core Transfer Program student learning outcomes linked exam questions. Other than question renumbering, 18 out of 20 questions on the two versions of the common final either were the same (3 ques-

tions) or tested the same outcome using slight wording and/or number variations (15 questions). The remaining 2 out of 20 questions on each version tested different outcomes and were not linked. Overall, the spring 2002 and spring 2003 distributions differed substantially, with a $p < 0.0001$. A “by question” comparison of spring 2002 and spring 2003 final exam correct response rates measured differences at the $\alpha = 0.03$ level of significance. From spring 2002 to spring 2003 correct response rates went up on 2 questions, went down on 6 questions, and remained statistically the same on 10 questions.

Rather than pursuing further study of these results, the department decided to remain with the same version of the common final from the 2002–3 to the 2003–4 assessment cycle to produce more reliable data to measure change between academic years.

Comparison between Entrance Exam and Common Final Exam

The department targeted two Core Transfer Program student learning outcomes,

- E. Work with formulas including formula evaluation and solving a formula for any of the variables, and
 - F. Read and analyze problems in the form of word problem applications and obtain solutions using equations,
- because of their relevance across department curricula and their harmony with the overarching departmental student learning outcomes. These outcomes tied the entrance exam and the common final to provide a means to measure student learning. Two questions on the entrance exam and three questions on the common final addressed these outcomes. Each student had a correct response count of 0, 1, or 2 on

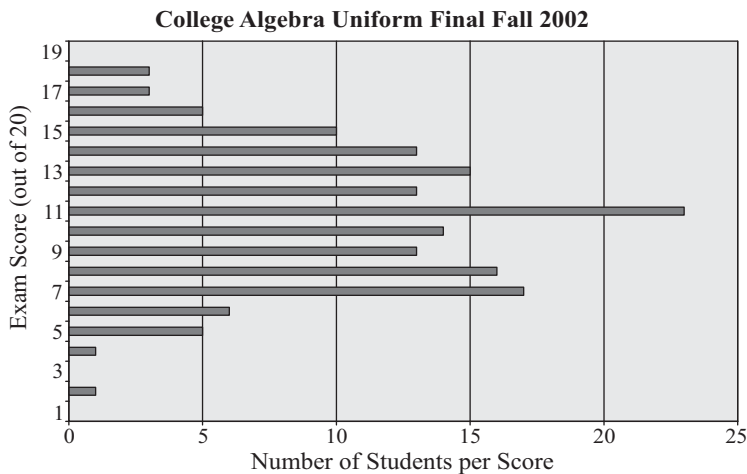


Figure 1. Distribution of Student Performance on Common Final Exam, Fall 2002.

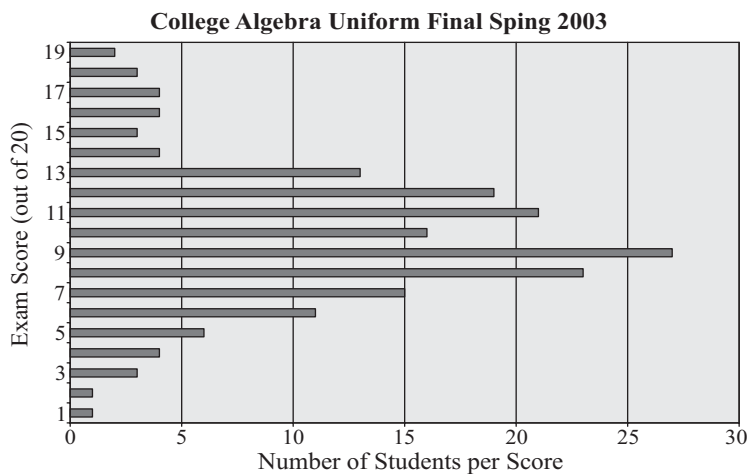


Figure 2. Distribution of Student Performance on Common Final Exam, Spring 2003.

Question	% Correct	Learning Outcome
19	88.33%	H
11	79.44%	K
15	79.44%	I
3	74.44%	I
17	72.22%	G
9	70.00%	E
18	69.44%	F
16	67.22%	H
4	63.89%	E
7	63.33%	H
12	63.33%	B
14	62.78%	B
5	57.78%	J
6	51.67%	H
10	48.33%	U
20	43.89%	F
13	42.78%	I
1	41.11%	O
8	41.11%	M
2	36.11%	F

Table 1. Rank Order of Student Performance on Questions on College Algebra Common Final Exam — Spring 2003

the entrance exam and 0, 1, 2, or 3 on the common final exam. The mean Fall 2002 and Spring 2003 entrance exam competency measurements were 1.52 (standard deviation 0.62) and 1.40 (standard deviation 0.66) respectively. The mean Fall 2002 and Spring 2003 final exam competency measurements were 1.71 (standard deviation 1.05) and 1.44 (standard deviation 1.00) respectively.

Investigation of degree of change in student competency between entrance and final exam was performed by computing the difference $d = p_2 - p_1$, where p_1 = proportion of correct responses on entrance exam and p_2 = proportion of correct responses on final exam. The mean value of d for Fall 2002 was -0.19 (standard deviation 0.41) and for Spring 2003 was -0.22 (standard deviation 0.41). Negative values of d reflect a reduction in relative rate of correct responses between entrance and final exam.

Contingency tables classified students by their entrance and final competency measures for Fall 2002 and Spring 2003. Concordance measure gamma for Fall 2002 was 0.29 and for Spring 2003 was 0.31. Hence, each semester has a limited degree of concordance between entrance and final competency, implying a slight tendency for higher scores on the entrance exam to be associated with higher scores on the final exam.

Insights

Improvement of student learning is the foundation of the assessment process. Rather than being a single event at the “end of the process”, changes that improve student learning

happen continuously throughout an effective assessment cycle. Refinement of the process, increased student awareness of expectations and involvement in assessment activities, constant faculty discussions of ineffective and/or improved pedagogical methods and subsequent decisions to modify pedagogy, and administrative support of program assessment efforts are some components of the assessment cycle that are integral to achieving the goal of improved student learning.

In the first of three components of the departmental assessment process, student common final correct response ranges indicate departmental strengths in Colorado Core Transfer Program student learning outcomes, B (63%, 63%), E (70%, 64%), F (69%), G (72%), H (88%, 67%, 63%, 52%), I (79%, 74%), J (58%), and K (79%) and departmental weaknesses in Colorado Core Transfer Program student learning outcomes, F (44%, 36%), I (43%), M(41%), O (41%), and U (49%). Learning outcomes F and I are identified as both strengths and weaknesses. Questions addressing outcomes F and I dealt with word problems and function notation/meaning respectively. The department will identify and address aspects indicating weaknesses in competencies F and I in the next assessment cycle. Questions indicating weaknesses in learning outcomes M, O, and U dealt with exponential and logarithmic equations, linear and nonlinear systems of equations, sequences, and series. Department faculty will discuss strengths and weaknesses and modify the College Algebra syllabus accordingly.

The second component of the department assessment process indicated no statistically significant difference

Outcome/Tool	Project or Portfolio	Standardized Exam	Pre-test/ Post-test	Faculty Survey	Student Survey
Students will acquire the ability to read, write, listen to, and speak mathematics.	CP2003				
Students will demonstrate a mastery of competencies identified by the competency-based syllabi for specific courses.	CP2003	CF2001	PP2002		
Students will use appropriate technology to enhance their mathematical thinking and understanding and to solve mathematical problems and judge the reasonableness of their results.	CP2003	CF2001			
Students will engage in substantial mathematical problem solving.	CP2003				
Students will acquire the ability to use multiple approaches—numerical, graphical, symbolic, and verbal—to solve mathematical problems.	CP2003				
CF2001 — College Algebra common final data collection and analysis began in 2001–2 academic year PP2002 — College Algebra entrance exam/common final data collection and analysis began in 2002–3 academic year CP2003 — Calculus I common projects with scoring rubric beginning in 2003–4 academic year					

Table 2. Assessment Methods Used to Measure Student Learning Outcomes

between the data from fall semester to spring semester during an academic year. The department has decided to collect another year of data to confirm the trend. If confirmed, the department will have the choice of either combining semester data into yearly data to increase statistical power or analyzing single semester data in an academic year to reduce resource requirements.

The third component of the department assessment process indicated a decrease in student performance on the two targeted Colorado Core Transfer Program student learning outcomes and a slight dependency of final competency on entrance competency. The decrease could be partly due to the fact that the two entrance exam questions were different from the three common final exam questions. The department decided to improve the method in 2003–4 by revising the entrance exam to include the three questions from the common final. Data collected using identical questions will allow statistically sound t-tests of proportions, contingency analysis, and logistic regression to better measure student learning during the course of the semester.

In its 2003–4 assessment cycle, the department will introduce an additional component to its assessment process. This additional component will be two common projects with associated scoring rubric in Calculus I. Students will receive a copy of the rubric with the project assignment. This component will assess all five discipline-level student learning outcomes and move the department toward the ACC Assessment Committee goal of assessing

all program-level student learning outcomes at least two ways by the 2004–5 academic year. Table 2 documents the department progress towards this Assessment Committee goal.

Acknowledgments

Department members have been aided by participation in the Mathematical Association of America's project Supporting Assessment in Undergraduate Mathematics (SAUM). Members of the department attended workshops in Burlington, Vermont in July 2002 and Baltimore, Maryland in January 2003, presented at a special SAUM session in Boulder, Colorado in August 2003, and participated in the SAUM poster session and the culmination of the workshop #2 series in Phoenix, Arizona in January 2004. Professional contacts and interchange with faculty across the nation involved in similar assessment activities and expert advice have been helpful in developing the ACC Mathematics Department assessment process. Further feedback from the SAUM publication effort will be incorporated into the department's assessment process.

Bibliography

1. *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus*. Memphis, TN, American Mathematical Association of Two-Year Colleges, 1995.