General Education Assessment of Quantitative Reasoning at the University of Houston

Miguel A. Ramos, Ph.D.
Leigh Hollyer, M.S.
Maureen G. Croft, Ph.D.

2008

Introduction

Quantitative reasoning is an integral part of the core curriculum at the University of Houston and a key focus of the general education assessment effort. By choosing to add this institutionally designated option to the state mandated core curriculum, the university recognizes the importance of student learning in this area.

Quantitative reasoning is a multi-faceted construct which is owned by several disciplines housed on our university campus. While an assessment framework that encompasses more than one discipline is warranted, a decision was made to implement a pilot study of quantitative reasoning in one discipline to test an assessment protocol and to determine the feasibility of implementing this protocol on a larger scale. At the University of Houston, mathematics lends itself well to such a project in part because math reasoning is a good proxy for quantitative reasoning but also because math tends to have well-defined learning objectives and student performance data.

In mathematics, quantitative reasoning is entwined with student competencies. If one were to consider Bloom's taxonomy, students must acquire knowledge before they can *apply* knowledge. Similarly, reasoning in mathematics is possible only after students have attained pre-reasoning skills, which include axiomatic knowledge (i.e., math rules). Therefore, the pilot study examined student outcomes with respect to not only reasoning skills but also the foundational learning that enables reasoning as defined by the math curriculum.

The assessment strategy for math competencies at the University of Houston reflects four general learning objectives adopted from the core curriculum guidelines established by the Texas Higher Education Coordinating Board (THECB) (Texas Higher Education Coordinating Board, 2008). Stated in terms of what students are expected to do, these objectives are:

- To apply arithmetic, algebraic, geometric, higher-order thinking, and statistical methods to modeling and solving real world problems
- To represent and evaluate basic mathematical information verbally, numerically, graphically, and symbolically
- To expand mathematical reasoning skills and formal logic to develop convincing mathematical arguments.
- To interpret mathematical models such as formulas, graphs, tables and schematics, and draw inferences from them

These learning objectives are consistent with the University of Houston core curriculum reasoning requirement that includes "building students' skills in mathematical and logical thinking" (University of Houston, 2008).

In order to assess student progress, the four learning objectives were mapped to four lower division courses.

- MATH 1310: College Algebra
- MATH 1313: Finite Mathematics with Applications
- MATH 1314: Calculus for Business and the Life Sciences
- MATH 1330: Pre-calculus

The rationale for choosing these particular courses is that a high proportion of undergraduates enroll in these classes as part of their degree plan. Thus, these courses provide the most appropriate data from which to study the acquisition of quantitative reasoning skills. (The reader is reminded that the quantitative reasoning construct is operationalized for the purposes of this pilot to be student work that reflects mathematical reasoning.)

Assessment Structure and Definitions

In order to assess the extent of student learning in math, the Mathematics Department collaborated with the University of Houston - Office of Institutional Effectiveness to identify specific courses and data items appropriate for the task. These courses and items represent an initial "pilot" framework that will guide the long term assessment strategy in this area.

I. Learning Objectives and Assessment Items

Table 1 maps specific exam items in four undergraduate math courses against the general education objectives for math competency. The selected items were reviewed by the math department – in collaboration with institutional research and assessment personnel – for their relevance and appropriateness to the specified learning objectives. It is important to note that a single test item may address more than one objective. For example, in the Table 1 the column for MATH 1330 contains two references to Item 4 from Test 2, addressing Objective 2 and Objective 4.

Table 1: Assessment Items by Course and Learning Objective*

Learning Objectives	Course			
	MATH 1310	MATH 1313	MATH 1314	MATH 1330
Objective 1: To apply arithmetic, algebraic, geometric, higher-order thinking, and statistical methods to modeling and solving real world problems	Test 2: **15**, **14**	Test 2: 6 Test 3: 2	Test 2: 2 Test 3: 4, **9** Test 4: 1, 7, 8	Test 3: 3 Test 4: 2, 9
Objective 2: To represent and evaluate basic mathematical information verbally, numerically, graphically, and symbolically	Test 4: 9, **10**, **11**	Test 2: **13** Test 3: 1, 3	Test 3: 5 Test 4: 2	Test 2: 4, 10 Test 4: **13**
Objective 3: To expand mathematical reasoning skills and formal logic to develop convincing mathematical arguments	Test 3: 6 Final: 3		Test 3: **9**	Test 3: **14** Test 4: 5, 6, **13**
Objective 4: To interpret mathematical models such as formulas, graphs, tables and schematics, and draw inferences for them	Test 3: 8 Test 4: 7	Test 2: 5, **13** Test 3: 5, 12	Test 3: 3, **9**	Test 2: 4, **16** Test 3: 12 Test 4: 5, 6

* Bold items represent free response questions

II. Item Type and Performance Levels

Exams represent the majority of assessments utilized by instructors in lower division mathematics courses. Therefore, the assessment strategy described here utilizes two types of data items: multiple choice (MC) and free response.

Item Difficulty

Math instructors and assessment staff routinely review the exams to evaluate the quality of the questions. Instructors also jointly determine item difficulty, which is rated on a three point scale of A, B, & C where "A" is most difficult and "C" is least difficult. In practical terms, an "A" level item requires "A" level understanding and skill, and a student earning an "A" in the class would be expected to answer the question correctly. A "B" level item requires "B" level comprehension and so on. Exams are constructed to have a mixture of A, B and C level questions so as to delineate differing levels of student understanding of concepts. As a result, interpretation of aggregate student performance on a given item must take item difficulty into account since the percentage of students answering a question correctly will likely vary depending on the difficulty of the questions. The item difficulty level is incorporated into the performance standards as illustrated in the following sections.

Performance Standards

The performance standards for the mathematics exams are derived from patterns of student outcomes in these courses from the past year. In short, the expected performance benchmark for A, B and C level questions was set by the average percent of students receiving

A's, B's and C's in the respective math courses during the previous year. **Table 2** provides the benchmarks for student performance relative to test item difficulty.

Table 2: Minimum Performance Benchmarks by Course and Item Difficulty

	Courses			
Item Difficulty Level	Math 1310	Math 1313	Math 1314	Math 1330
A Level	22%	22%	21%	16%
B Level	44%	42%	44%	34%
C Level	60%	60%	59%	52%

In terms of multiple choice items, the figures above represent the minimum acceptable percentage correct for a given item difficulty. For example, if 61% of students in Math 1310 answer a "C" level item correctly, they will have met the standard of performance for that item.

The rationale for free response items is similar. In this case, the percentages from Table 2 indicate the minimum group performance expectation for each free response item defined as the proportion of responses that are "acceptable" or better. For instance, 42% of students in Math 1313 would be expected to provide an "acceptable" or "exemplary" answer to a "B" level free response item. In Math 1330, the group performance expectation would be 34% for the same item

Performance Levels for Multiple Choice Items

Performance standards for each type of item are slightly different and bear additional discussion. Standards for multiple choice items are applied to aggregate student results. Put simply, did students as a group do well enough on an item to demonstrate adequate learning at the program level? As mentioned previously, the performance standards are divided into three tiers to account for item difficulty. If an item represents "A" level content, then the percentage of students expected to answer that item correctly would be lower relative to the expectation for a "C" level question.

Performance Levels for Free Response Items

While multiple choice items primarily result in binary outcomes (correct vs. incorrect), free responses require a more complex grading system. Each free response item is composed of multiple parts and points are awarded cumulatively. In other words, success on later components of the problem is dependent on how well students perform on earlier stages. The more a student knows and understands the course material, the higher the likelihood of the student answering a given item accurately and completely. Points are assigned accordingly. Since the total point values for each question different slightly depending on the number of item components, the math department has set specific performance cut points for each item. Regardless of the total number of points, performance on each item is expressed in terms of four performance levels. These are:

Needs Improvement: Student is lacking the prerequisite skills necessary to take the first step towards solving the problem.

Basic: Student has demonstrated that he/she has the pre-requisite skills to set up the problem and/or take the first step towards solving the problem.

Acceptable: Student has demonstrated sufficient knowledge to solve the problem.

Exemplary: Student has completed every step required to solve the problem correctly and has reported the answer correctly.

Although there are four possible student performance levels, the critical cut score is the point at which students are classified as "acceptable" since this represents the minimum math target outcome for these items. It is reasonable to assume that difficult items will have fewer students attaining acceptable status compared to less difficult items. Therefore, different cut points are set based on the three item difficulty levels (e.g. A, B, and C). The actual performance standards (i.e. minimum percentage needed for each performance level) are based on student outcome patterns in previous courses.

Results

The results of the item analysis are organized by learning objective. This allows us to address individual objectives in terms of student performance on the appropriate items relative to the standards. The columns titled "% Correct" and "% Acceptable or higher" provide the actual student assessment results while a check in the "Met Standard" column indicates whether the overall aggregate results meet the threshold of acceptable performance as described in the previous section when factoring in item difficulty. Please note that item difficulty is indicated by a letter after each item in the tables (e.g. Test 2:15 (B)).

Objective 1: To apply arithmetic, algebraic, geometric, higher-order thinking, and statistical methods to modeling and solving real world problems

Course	MC Items	% Correct	Met Standard	Free Response Items	% Acceptable or higher	Met Standard
MATH 1310				Test 2: 15 (B)	81%	✓
				Test 2: 14 (A)	67%	✓
MATH 1313	Test 2: 6 (C)	93%	✓			
	Test 3: 2 (C)	49%	-			
MATH 1314	Test 2: 2 (B)	52%	✓			
	Test 3: 4 (C)	95%	✓			
	Test 4: 1 (B)	85%	✓	Test 3: 9 (A)	68%	✓
	Test 4: 7 (A)	60%	✓			
	Test 4: 8 (B)	62%	✓			
MATH 1330	Test 3: 3 (C)	65%	✓			
	Test 4: 2 (C)	43%	-			
	Test 4: 9 (A)	49%	✓			

Objective 2: To represent and evaluate basic mathematical information verbally, numerically, graphically, and symbolically

Course	MC Items	% Correct	Met Standard	Free Response Items	% Acceptable or higher	Met Standard
MATH 1310	Test 4: 9 (A)	66%	✓	Test 4: 10 (B)	51%	✓
				Test 4: 11 (B)	32%	-
MATH 1313	Test 3: 1 (C)	81%	✓	Test 2: 13 (B)	68%	✓
	Test 3: 3 (C)	74%	✓			
MATH 1314	Test 3: 5 (B)	46%	✓			
	Test 4: 2 (A)	96%	✓			
MATH 1330	Test 2: 4 (B)	56%	✓	Test 4: 13 (A)	24%	✓
	Test 2: 10 (A)	45%	✓			

Objective 3: To expand mathematical reasoning skills and formal logic to develop convincing mathematical arguments.

Course	MC Items	% Correct	Met Standard	Free Response Items	% Acceptable or higher	Met Standard
MATH 1310	Test 3: 6 (C)	81%	✓			
	Final: 3 (C)	93%				
MATH 1314				Test 3: 9 (A)	68%	✓
MATH 1330	Test 4: 5 (A)	54%	✓	Test 3: 14 (A)	52%	✓
	Test 4: 6 (A)	54%	✓	Test 4: 13 (A)	24%	✓

Objective 4: To interpret mathematical models such as formulas, graphs, tables and schematics, and draw inferences for them

Course	MC Items	% Correct	Met Standard	Free Response Items	% Acceptable or higher	Met Standard
MATH 1310	Test 3: 8 (B)	71%	✓			
	Test 4: 7 (C)	74%	✓			
MATH 1313	Test 2: 5 (C)	79%	✓	Test 2: 13 (B)	68%	✓
	Test 3: 5 (C)	87%	✓			
	Test 3: 12 (A)	39%	✓			
MATH 1314	Test 3: 3 (B)	46%	✓	Test 3: 9 (A)	68%	✓
MATH 1330	Test 2: 4 (B)	56%	✓	Test 2: 16 (B)	35%	✓
	Test 3: 12 (A)	78%	✓			
	Test 4: 5 (A)	54%	✓			
	Test 4: 6 (A)	54%	✓			

In sum, results indicate that students are meeting the general education benchmarks for acceptable performance in mathematics. Outcome data for each objective suggest that students are able to demonstrate learning at a level consistent with the goals of the math program. The range of item difficulty provides additional insight regarding the depth of knowledge acquired by students across the available courses.

Discussion

The assessment process described in this report represents the first phase of a multi-year strategy to refine how the university evaluates student progress in quantitative reasoning skill acquisition. The results of this study will lead to a two-pronged assessment strategy. First, there will be continued development and refinement of the general math component of core curriculum assessment. Secondly, the university will expand the scope of quantitative reasoning assessment to include the other university disciplines that own the responsibility for teaching these skills. Each of these projects will be discussed in turn.

General Math Assessment – Next Steps

Mathematics faculty will undertake a review of these objectives to determine whether these should be revised to better address our students' needs. The first stage of the review (FY 2008/2009) will utilize instructors from the four courses described in this report. However, the math department will continue to map exam items to the appropriate objectives for evaluative purposes only making changes when appropriate and consistent with the overall assessment approach.

In FY 2009-10, the scope of assessment will be expanded to incorporate additional courses. This will provide a wider net for gauging general student learning in math. It is likely that the first course to be added to this process is MATH 2311: Introduction to Probability and Statistics. The class provides foundational knowledge in an area of mathematics that permeates everyday life and is in keeping with mission of the university to create quantitatively literate graduates.

Quantitative Reasoning – Next Steps

Within the framework of the university curriculum, mathematics and quantitative reasoning represent parallel learning paths. As discussed previously, quantitative reasoning is not owned by a single discipline. Quantitative reasoning skills may be learned in fields such as philosophy, computer science, and music. This pilot study provides a springboard for interdisciplinary discussions with respect to quantitative reasoning at the University of Houston. The ultimate goal is to develop a general education assessment protocol that incorporates the relevant skills and knowledge from each of these disciplines into a comprehensive continuous improvement plan.

References

Texas Higher Education Coordinating Board (2008). Core curriculum: assumptions and defining characteristics. THECB Website. Retrieved March 25, 2007 from http://www.thecb.state.tx.us/AAR/UndergraduateEd/fos_assumpdef.cfm

University of Houston (2008). Degree requirements: core curriculum requirements. The University of Houston Website. Retrieved March 25, 2007 from http://www.uh.edu/academics/catalog/general/acade3.html#core_req