

An Assessment of General Education Mathematics Courses' Contribution to Quantitative Literacy

Aimee J. Ellington
Department of Mathematics
Virginia Commonwealth University
Richmond, VA
ajellington@vcu.edu

Abstract. This study was conducted to determine the role general education mathematics courses play in the development of the quantitative reasoning skills of students enrolled in those courses. The students' post-test results on a series of quantitative literacy questions were compared with pretest baseline results. The assessment revealed that the quantitative reasoning skills of students are improved through participation in general education mathematics courses.

Background and purpose

The twenty first century promises to be an age of information and technology. Much of the information we gather throughout a normal day is quantitative data. Understanding the world and all of its complexities requires a strong sense of numerical data and the quantitative measures used to gather and evaluate numerical information. Quantitative literacy or numeracy, as it is sometimes called, is an essential skill for well-informed citizens. In a typical college or university, at least half of the population consists of students majoring in a field that is not based in science, engineering, or mathematics. As one quantitative literacy expert recently stated, "numeracy, not calculus, is the key to understanding our data-drenched society" [1]. As a result, the quantitative reasoning skills of all students, whether they are working toward a mathematically intensive major or not, must be addressed by institutions of higher education.

Virginia Commonwealth University (VCU) is an urban institution located in Richmond. The diverse student population consists of 25,000 individuals enrolled in 130 graduate and undergraduate degree programs. The State Council of Higher Education for Virginia (SCHEV) is encouraging accountability in Virginia's higher education institutions by publishing a series of Reports on Institutional Effectiveness (ROIE) [2]. These reports are intended to provide educators, policy makers, and prospective students with information about the academic quality of higher education institutions in Virginia. A forthcoming ROIE will focus on the quantitative reasoning skills of graduates of Virginia's public institutions. Based on the SCHEV mandate, the VCU Assistant Provost requested that the Mathematics Department begin the process of assessing the quantitative literacy of VCU graduates.

The goal of the assessment outlined below is to determine the role of VCU general education mathematics courses in improving the quantitative reasoning skills of students who complete the courses. In particular, this project is to determine if VCU is preparing more quantitatively literate graduates through its general education mathematics courses. The assessment focuses on the impact of four entry level mathematics courses: Math 131, Contemporary Mathematics; Math 141, College Algebra; Math 151, Precalculus; and Math 200, Calculus I.

Math 131 is an activity-based course where students are engaged in developing skills needed in real-world situations. Out of the four courses, Math 131 is the class that most directly covers quantitative reasoning topics. On a regular basis, students convert a real-world situation to a mathematical problem, solve the problem and then apply what they learned to the original situation. The students are encouraged

to write about mathematics on a weekly basis. Throughout the semester, they participate in hands-on experiments, are engaged in discussions about quantitative topics, and prepare poster presentations on topics with quantitative components.

The three remaining courses are more traditional mathematics courses that do not explicitly focus on quantitative reasoning skills. Math 141 is a large lecture college algebra course designed to strengthen fundamental skills before students take more advanced mathematics courses. Math 151 covers the traditional precalculus topics in small lecture-based class meetings. Math 200 is taught in relatively small classes with a textbook that features both reform and traditional calculus methods.

Method

In Fall 2001, we conducted a search for an instrument appropriate for assessing quantitative reasoning skills. Several instruments designed by faculty at various higher education institutions were evaluated, but none were considered appropriate for the VCU project. As a result, a committee was formed to design a test instrument for the assessment project. Through a series of brainstorming sessions a set of twenty-five multiple choice questions was created. A preliminary test of the questions was conducted with students taking Math 131 and Math 151 final exams in May 2002. Student responses were evaluated to determine whether the questions were appropriate for the assessment and the level of difficulty of the questions. Feedback on the questions and responses was also gathered from colleagues from colleges and universities participating in an assessment workshop sponsored by the Mathematical Association of America. Based on these activities, changes were made to existing questions, some questions were eliminated, and other questions were added yielding a final set of sixteen quantitative literacy questions. Two examples appear in Appendix A; the complete list of questions can be obtained from the author. The multiple-choice questions cover a wide range of quantitative literacy topics. A list of topics and the questions used to assess each topic appear in Table 1 of Appendix B. Many questions in the test bank cover more than one numeracy category.

More than a decade ago, four items on the mathematics placement test were made available for assessment projects. For the current assessment project, four questions from the bank of quantitative reasoning questions were used as the placement test assessment project items. Since there are four versions of the placement test each one contains four different assessment project questions. The same four sets of four questions were included on versions of final exams given at

the end of the courses. The types of questions were equally distributed on the placement tests and the final exams.

Test data was gathered over three semesters from Fall 2002 to Fall 2003 from students taking both the placement test and one of the aforementioned courses. No students were excluded from the assessment. Through an extra credit incentive, students were encouraged to answer the questions on the final exams. They were given a bonus of one point on the exam grade for each question answered correctly. Table 2 in Appendix B contains the number of students completing each version of the placement tests and the final exams. The data and results reported below are for all four courses combined, as well as for Math 131 alone.

The data gathered on correct responses to each question on the mathematics placement test was used to generate a baseline percentage. The percentage reflects the proportion of the incoming student population with an understanding of the numeracy concept upon which the question was based. For each question, a statistical comparison was conducted of the proportion of students answering the question correctly on the placement test with the proportion of students who took the placement test answering the question correctly on the final exam. The combined results for all classes as well as the results for Math 131 alone were analyzed. A significant result ($p < .05$) was obtained when the proportion of students answering the question on the final exam correctly was statistically larger than the proportion of students answering the question correctly on the mathematics placement test. This was used to determine that taking a VCU general education mathematics course had resulted in a larger proportion of students understanding the quantitative reasoning concept covered by that question.

Findings

Table 3 of Appendix B contains the combined results for all classes. The placement test column contains the baseline percentage of correct responses to which the final exam percentage of correct responses was statistically compared. The percentages listed in the final exam column that are marked with an asterisk are the percentages that were statistically larger than the corresponding placement test percentage. The percentage of students answering the final exam question correctly was significantly larger than the baseline percentage for all but three questions. Question 2 was a graph interpretation question with a low level of difficulty. Questions 7 and 14 were more difficult questions on proportional reasoning and percent increase.

While numeracy topics are not a direct focus of instruction in Math 141, 151, and 200, it appears that all general educa-

tion mathematics courses are helping students develop quantitative reasoning skills. Students in these courses are at least indirectly exposed to the topics featured in the assessment questions. Unit analysis is part of the college algebra curriculum. Exponential functions are featured in precalculus. All three courses spend a great deal of time on the analysis of graphs and the use of mathematical functions.

Since Math 131 is the course that specifically covers quantitative reasoning topics, the results for this course were analyzed separately. The percentages appear in Table 4 in Appendix B. There was concern that one aspect of the placement test might result in low baseline percentages. A placement level is generated by the number of correct responses minus one-fourth of the number of incorrect responses. As a result, the instructions state that if a student is uncertain about a response, it is acceptable to not provide an answer to that question. In Fall 2002, over 40% of students placed in Math 131 left questions 4 and 8 blank when they took the placement test. However, this was not the case in Spring and Fall 2003. The low percentages (questions 7 and 10) are not due to a large number of students not answering the questions. They are simply the result of a small number of students choosing the correct response.

The results for Math 131 were mixed. No topic-related patterns could be drawn from the statistically significant results. For example, for the two questions that featured proportional reasoning, the percentage of students answering one question correctly on the final exam was significantly greater than the percentage of students answering the same question correctly on the placement test. The result for the other question was not statistically significant. This was true for all but one of the numeracy constructs that were assessed by two or more questions. Based on the results, the ability to interpret charts and graphs is no different after students complete Math 131.

Use of Findings

The findings for all classes reveal that general education mathematics courses at VCU are playing a role in helping students develop quantitative reasoning skills. The results are also pinpointing aspects of quantitative reasoning that are difficult for students to understand. Determining the relevance of these topics to college algebra, precalculus, and calculus will be the focus of discussion among VCU mathematics faculty. Based on these discussions, we are considering changes in the curricula of these courses. In particular, VCU is planning to teach several small sections (approximately 35 students) of Math 141 with a textbook that highlights problem solving and the use of real-world

applications. The graphing calculator will be a major tool in these sections to allow the course to focus on conceptual understanding with less emphasis on skill development when compared to a traditional college algebra course.

As noted above, for all but three questions in the combined results, the percentage of students getting a question correct on the final exam was significantly higher than the percentage of students getting the same question correct on the placement test. Nevertheless, the final exam percentages for many questions were still low. For the combined results, the percentage of correct responses on final exams was less than 50% for 11 of the 16 questions. The same is true for students who completed Math 131. Therefore, we will be looking at ways to ensure that larger percentages of students complete general education mathematics courses with an understanding of these numeracy topics.

The results for Math 131 in particular do not reflect the level of quantitative reasoning we hope students are developing as they take the course. One possible reason is that many aspects of Math 131 can not be assessed through the set of multiple choice questions that were developed for this project. Traditional instructor-led lectures take place in only one-third of the course time while the rest of the class time is spent with students engaging in group discussions, hands-on activities, and working on long term projects. Written responses to assigned problems are required. In addition to daily assignments, students use their quantitative reasoning skills to write several papers in the course and give a poster presentation at the end of the semester. All student work is graded and none of the assessment instruments feature multiple choice questions. Based on the fact that 69.4% of the students who took the course during the time frame of this project received an A, B, or C as their final grade, the majority of students taking the course are achieving the quantitative reasoning goals established for the course. We will continue to analyze the topics covered and the methods of assessment used in Math 131 to determine whether or not changes are warranted.

Through this assessment, the VCU mathematics faculty has acquired valuable information upon which to base curricular changes. In particular, the students who participated in this assessment had difficulty with the questions involving unit analysis, proportional reasoning, and percent increase or decrease. The VCU mathematics faculty will be looking for ways to improve the instruction in the content areas related to these questions.

Success Factors

Several factors helped make this assessment project a success. First, having several questions on the mathematics

placement test available for assessment purposes was essential for gathering baseline data. Second, pilot testing the questions and getting input from colleagues at an assessment workshop helped solidify our bank of questions. The workshop discussions also were beneficial in narrowing the focus of the assessment project. Lastly, the support of VCU faculty was essential to the project. All instructors of general education mathematics courses readily made the assessment questions the last page of their final exams and gave their students extra credit for each question answered cor-

rectly. Without their willingness to participate, this project would not have been possible.

References

1. State Council of Higher Education for Virginia “2002 Reports of Institutional Effectiveness” webpage <http://roie.schev.edu/>
2. Steen, L. A. “Numeracy: The New Literacy for a Data-Drenched Society.” *Educational Leadership*, 57 (2), October 1999, pp. 8–14.

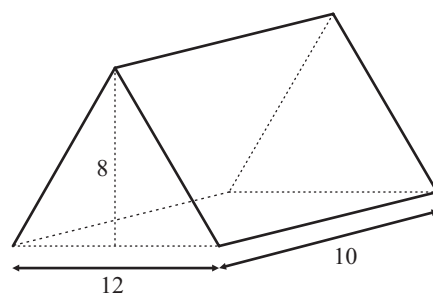
Appendix A. Examples of Questions Used to Assess Quantitative Literacy

Example #1 An “A” tent is one that is open in the front and back and has no floor. For an outdoor project you need an “A” tent that is 10 ft long, 8 ft high and has a 12 ft wide opening. What are the dimensions of the tarp you need to construct the tent?

- a. 10 ft \times 12 ft b. 12 ft \times 20 ft c. 10 ft \times 20 ft
d. 10 ft \times 24 ft e. 16 ft \times 10 ft

Example #2 The population of a county is 100,000. A power company predicts that the population will increase by 7% per year. The county supervisors predict that the population will increase by 7,500 each year. Which group’s prediction method predicts the larger population in 10 years?

- a. supervisors
b. power company
c. both predictions are the same after 10 years
d. There is not enough information provided to answer the question.



Appendix B. Analysis of Quantitative Literacy Assessment

Topic	Question Number
Unit Analysis	1, 7, 9, 13
Interpretation of Charts and Graphs	2, 6, 10
Proportional Reasoning	7, 13
Counting Principles	8
General Percents	3, 6, 11
Percent Increase or Decrease	4, 12, 14
Use of Mathematical Formulas	1, 5, 9, 12, 15, 16
Average	16
Exponential Growth	12

Table 1. Breakdown of Questions by Quantitative Literacy Topic

Test Version	All Classes		Math 131	
	Placement Test	Final Exam	Placement Test	Final Exam
1. Questions 1 – 4	452	489	131	126
2. Questions 5 – 8	551	454	158	127
3. Questions 9 – 12	506	520	140	157
4. Questions 13 – 16	449	495	125	144

Table 2. Number of Student Responses by Question

Question Number	Placement Test	Final Exam	Question Number	Placement Test	Final Exam
1	34.96	45.60*	9	29.11	42.69*
2	84.73	81.80	10	11.07	17.88*
3	25.44	33.95*	11	63.17	75.19*
4	24.78	39.26*	12	22.73	42.88*
5	30.67	42.29*	13	58.48	65.25*
6	38.48	46.26*	14	15.85	18.18
7	13.25	16.52	15	65.70	86.26*
8	24.14	44.49*	16	41.87	63.23*

* Significantly larger percentage, $p < .05$

Table 3. Percentage of Correct Responses for All Four Courses

Question Number	Placement Test	Final Exam	Question Number	Placement Test	Final Exam
1	35.11	31.75	9	26.43	36.31*
2	82.44	78.57	10	8.57	12.10
3	19.85	25.40	11	58.57	76.43*
4	19.08	25.40	12	15.00	38.85*
5	26.58	37.80*	13	43.55	58.33*
6	30.38	35.43	14	16.00	15.97*
7	9.49	11.02	15	53.60	77.08*
8	22.15	37.80*	16	36.00	58.33*

* Significantly larger percentage, $p < .05$

Table 4. Percentage of Correct Responses for Math 131, Contemporary Mathematics