UNIVERSITY OF LA VERNE

Quantitative Reasoning Assessment:
GE Critical Skill Learning Outcome

Spring 2011

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Executive Summary

Purpose
The purpose of this assessment was to gather actionable evidence to demonstrate the extent to which the General Education Critical Skills learning outcome of Quantitative Reasoning was being acquired.

The Quantitative Reasoning Learning Outcomes are as follows:
1. Represent mathematical information symbolically, visually, numerically, and verbally
2. Interpret and draw inference from mathematical models such as formulas, graphs, tables, and schematics
3. Apply arithmetical, algebraic, geometric and statistical methods with appropriate technological tools to solve problems
4. Think critically and apply commonsense in estimating and checking answers to mathematical problems in order to determine reasonableness, identify alternatives, and select optimal results

Method and Procedure
Direct Measure

Altogether 14 sets of exams from 14 different courses in the fall 2010, designated as meeting the General Education Quantitative Reasoning requirement, were obtained for analysis. The set of 14 exams included 5 Algebra, 5 Statistics, 3 Calculus, and 1 Math in Society. From each exam, 3 to 6 questions were selected as being representative of one or more of the four learning outcomes. A total of 65 questions were identified for assessment across all 14 sets. For each of the 14 sets of exams 5 test papers were randomly selected involving a total of 70 students. A 4-point rubric was used to evaluate each learning outcome: 4 = Accomplished, 3 = Developed, 2 = Developing, and 1 = Undeveloped. Using the rubric, two mathematics professors evaluated/graded every problem for all students, and for all learning outcomes.

Indirect Measures
Archival data from the College Senior Survey (CSS 2009) and the National Survey of Student Engagement (NSSE 2010, and 2011 pilot) were used to assess the self-reported competencies in quantitative reasoning by freshman and seniors, and their degree of engagement in related learning activities.

Findings
Skills in representing quantitative information, interpreting and drawing inferences from data, and applying quantitative information to solve problems are achieved fairly well ("Accomplished" and Developed"), with room for improvement. Skills involving thinking

critically and applying common sense to select optimal results are less well acquired. Generally, these learning outcomes appear to be better achieved in applied courses such as Statistics and Math in Society.

Taken together, the indirect self-report measures suggest that La Verne is contributing to students' development of overall quantitative skills, and that their experiences engage them with related activities.

Action Recommendations

1. Revise the rubric to include a zero rating to reflect the complete absence of an attempt to respond to the question, or for having missed the point altogether.
2. Present these findings to the General Education Committee for a discussion of the way Quantitative Reasoning Learning Outcomes are stated, and the criteria for approving courses to meet the GE requirement.
3. Lead a discussion of the faculty who teach the GE Quantitative Reasoning courses to reflect about classroom experiences that relate to the learning outcomes, and about ways of being more explicit in connecting assessments to the GE outcomes.
4. Consider a senior exit exam or a nationally standardized test to assess Quantitative Reasoning skills.
5. Familiarize mathematics tutors at the Learning Enhancement Center with the Quantitative Reasoning Learning Outcomes.

Table of Contents

Purpose

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Quantitative Reasoning Learning Outcomes
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Direct Measure

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The problems were selected as reflecting competence in one or more of the four learning outcomes. The same 3 to 6 problems were graded from all 5 student test papers selected from a particular course. Many of the problems were evaluated for multiple learning outcomes. Table 1 below summarizes some of the methodological information. As may be seen, the number of problems that addressed a particular outcome varied from 15 to 37, and the number of instances/times a particular outcome was evaluated varied from 74 to 183.

Table 1
Information regarding number of students, tests, problems, and times or instances each outcome was evaluated

Learning Outcomes	Number of tests addressing outcome	Number of students from each test	Number of problems addressing outcome	Number of times/instances outcome was evaluated
1. **Represent** Mathematical information symbolically, visually numerically and verbally	14	5	20	101
2. **Interpret and draw inference** from mathematical models such as formulas, graphs, tables, and schematics	14	5	20	100
3. **Apply** arithmetical, algebraic, geometric and statistical methods with appropriate technological **tools to solve problems**	14	5	37	183
4. **Think critically** and apply commonsense in estimating and **checking answers** to mathematical problems in order to determine reasonableness, identify alternatives, and select optimal results	12	5	15	74

Notes:
1. Altogether 14 GE approved classes provided tests or exams for assessment (Algebra = 5, Statistics = 5, Calculus = 3, Math in Society = 1)
2. Altogether 70 students were randomly selected for assessment, 5 from each test or exam
3. Altogether 263 student tests or exams were submitted for assessment
4. Altogether 65 problems were identified across all tests or exams for assessment; several problems were used to assess multiple outcomes

A 4-point rubric was developed to evaluate each learning outcome: 4 = Accomplished, 3 = Developed, 2 = Developing, and 1 = Undeveloped (See Appendix A). Using the rubric, two mathematics professors evaluated/graded every problem for all students, and for all learning outcomes. Whenever the two graders differed by more than one point, the problem was re-examined and an adjustment made to bring the grades to within one point (or equal). If there was a difference of 1 point between the two graders, the score for that problem and learning outcome was the mean of the two scores. Evaluators suggested revising the rubric somewhat for future efforts to include a zero rating to reflect if the student has completely missed the point or has not made a serious attempt to respond to a question.

Indirect Measures

Archival data from the College Senior Survey (CSS) and the National Survey of Student Engagement (NSSE) were used to assess the self-reported competencies in quantitative reasoning by freshman and seniors. CSS or NSSE data are collected electronically at the end of the academic year independently by the managing organizations of these surveys. La Verne provides names and contact information. The following questions related to quantitative skills were considered:
1. Compared to your peers how would you describe your mathematical skills (CSS 2009)?
2. To what extend has your experience at this institution contributed to your knowledge, skills, and personal development in analyzing quantitative problems (NSSE 2010)?
3. How much has your experiences at this institution contributed to your knowledge, skills, and personal development in analyzing numerical and statistical information (NSSE 2.0 2011 pilot survey to be released 2013)?

Additionally, questions related to how often freshman and seniors engaged in quantitative reasoning related activities were examined from the NSSE 2.0 2011 pilot:
In your experience at your institution during the current year, about how often have you
1. Reached conclusions based on your own analysis of numbers, graphs, and statistics?
2. Used numbers, graphs, or statistics to help analyze a contemporary or historical issue (Poverty, climate warming, etc.)?
3. Explained in writing the meaning of numbers, graphs, or statistics?
4. Analyzed others' conclusions by using numbers, graphs, or statistics?

Findings

Direct Measures

Table 2 below shows the mean ratings associated with each learning outcome and type of class, as well as the combined totals across types of classes. Table 3 below shows the percentage of times or instances learning outcomes were rated as "Accomplished" or "Developed." Overall, the mean ratings are over 3.00 (Developed) for the firsts three learning outcomes, and below 3.00 for the fourth. The first and second learning outcomes have received ratings of "Accomplished" or "Developed" in 70 and 71 percent of the instances of evaluation, respectively. The third and fourth learning outcomes have received such ratings in 68 and 63 percent of the instances of evaluation, respectively.

Table 2
Means, Standard Deviations (in parentheses), and One-Way ANOVAs of the four Quantitative Reasoning learning outcome rated on a 4-point scale (4 being Accomplished, the highest score; 3 = Developed, 2 = Developing, and 1 = Undeveloped) for different types of classes (Algebra-5 classes, Statistics-5 classes, Calculus-3 classes, and Math in Society-1 class) (N = Number of times/instances outcome was evaluated)

Learning outcome	Total		Type of Class: Algebra		Statistics		Calculus		Math in Society	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
1. **Represent** Mathematical information symbolically, visually numerically and verbally ($F = 8.92$, $p < 001$)*	101	3.13(1.15)	30	2.35(1.09)	45	3.53(1.05)	21	3.19(.99)	5	3.90 (.22)
2. **Interpret and draw inference** from mathematical models such as formulas, graphs, tables, and schematics ($F = 8.60$, $p < .001$)	100	3.16(1.15)	30	2.36(1.11)	45	3.53(1.05)	20	3.35(1.05)	5	3.90(.22)
3. **Apply** arithmetical, algebraic, geometric and statistical methods with appropriate technological **tools to solve problems** ($F = 8.02$, $p <.001$)	183	3.07(1.12)	74	2.75(1.14)	50	3.67(.84)	44	2.89(1.21)	15	3.27(.82)
4. **Think critically** and apply commonsense in estimating and **checking answers** to mathematical problems in order to determine reasonableness, identify alternatives, and **select optimal results** ($F = 3.60$, $p = .018$)	74	2.93(1.26)	25	2.62(1.45)	25	3.54(.91)	19	2.50(1.26)	5	3.20(.57)

* There were statistically significant differences between the Types of Classes for all learning outcomes

Table 3
Percentage of "Accomplished" and "Developed" competencies of the four Quantitative Reasoning learning outcome rated on a 4-point scale (4 being Accomplished, the highest score; 3 = Developed, 2 = Developing, and 1 = Undeveloped) for different types of tests (Algebra - 5 classes, Statistics - 5 classes, Calculus - 3 classes, and Math in Society - 1 class) (N = Number of times/instances outcome was evaluated)

	Type of Class									
Learning Outcome	Total		Algebra		Statistics		Calculus		Math in Society	
	N	%	N	%	N	%	N	%	N	%
1. **Represent** Mathematical information symbolically, visually numerically and verbally	101	70	30	42	45	85	21	71	5	100
2. **Interpret and draw inference** from mathematical models such as formulas, graphs, tables, and schematics	100	71	30	42	45	85	20	75	5	100
3. **Apply** arithmetical, algebraic, geometric and statistical methods with appropriate technological **tools to solve problems**	183	68	74	55	50	90	44	61	15	86
4. **Think critically** and apply commonsense in estimating and **checking answers** to mathematical problems in order to determine reasonableness, identify alternatives, and **select optimal results**	74	63	25	52	25	84	19	42	5	80

On the whole it looks like the first three learning outcomes are being met quite well, with the forth one lagging behind a little. Skills in representing quantitative information, interpreting and drawing inferences from data, and applying quantitative information to solve problems are achieved fairly well. Skills involving thinking critically and applying common sense to select optimal results seem to be less well acquired (Learning outcome 4).

Examining performance levels in different class types strongly suggests that these learning outcomes are acquired at significantly higher levels in "applied" courses such as Statistics and Math in Society (over 80% of instances rated as Accomplished or Developed), than in Algebra or Calculus. Calculus courses seem to be doing a little better than Algebra courses in meeting the first two learning outcomes of representing quantitative data (71%), and interpreting and drawing inferences (75%).

Taken together, direct performance measures of quantitative reasoning learning outcomes suggest fairly strong acquisition of the 3 out of 4 of the outcomes with room for improvement. Students in applied GE quantitative reasoning courses such as statistics appear to be doing somewhat better in achieving these outcomes. While the nature and variability of problems across courses used for assessment may be a possible threat to the reliability of the scoring, it may be seen also as providing a good cross-section of authentic student performance indicators. The rubric seems to have captured well the variation in the achievement levels of the learning outcomes, and able to establish consensus between the raters.

Indirect Measures

A. Engagement with quantitative information

The NSSE 2.0 survey results below in Table 4 from the 2011 pilot show the degree of engagement with quantitative information as part of college experience. It should be noted that in this and other CSS and NSSE surveys freshmen samples comprise predominantly traditional-age students, while senior samples comprise predominantly non-traditional-age students.

Table 4
Questions in the NSSE 2.0 2011 beta testing pilot (to be released 2013)

	Freshmen		Seniors	
	N	% *(Often/Very Often)*	N	%*(Often/Very Often)*
In your experiences at your institution during the current year, about how often have you:				
b. **Reached conclusions** based on your own analysis of numbers, graphs, or statistics	158	56%	450	61%
c. **Used numbers,** graphs, or statistics to help **analyze** a contemporary or historical **issue** (Poverty, climate change, etc)	159	37%	452	50%
d. **Explained** in writing the meaning of numbers, graphs, or statistics	159	40%	447	49%
e. **Analyzed** others' **conclusions** by using numbers, graphs, or statistics	157	35%	449	42%

These data and all the other self-report data from CSS or NSSE are collected at the end of the academic year. For freshman this means they are responding to the questions involving experiences in their first year at La Verne. The activities indicated in these questions seem to touch broadly on the issues addressed in the learning outcomes assessed here, such as representing data, drawing inferences and conclusions, and applying and interpreting quantitative information.

The data suggest that in all areas assessed, not surprisingly, more seniors report engaging with quantitative information often or very often (42% to 61%) in their academic experiences than freshmen. However, it is encouraging to see that substantive numbers of freshmen (35% to 56%) are engaged also with quantitative information.

B. Self-reported gains in quantitative skills

Table 5 below presents the responses to questions dealing with gains in quantitative skills on CSS and NSSE surveys. On the CSS 2009 survey about 3 out of 10 senior students describe their mathematics skills being in the highest 10% or above average compared to their peers, with more men saying so than women. In the comparison group of Non-Sectarian 4-year colleges more student make such claims about their mathematics skills. The comparison group includes a number of colleges that are more selective than La Verne.

As expected, on the NSSE 2010 survey seniors rate significantly higher than freshmen La Verne's contribution to their knowledge, skills and personal development in analyzing quantitative problems. Among seniors, traditional-age students rate La Verne's contribution to their mathematical skills significantly higher than non-traditional-age students.

Responses on the NSSE 2.0 2011 pilot survey to a somewhat different question show a similar trend. About 3 out of 4 seniors (73%) compared to 2 out of 4 freshmen (47%) indicate as "quite a bit" and "very much" La Verne's contributed to their knowledge, skills, and personal development in analyzing numerical and statistical information. Responses of traditional and non-traditional student responses are not provided at this time.

Taken together, the indirect self-report measures suggest that La Verne is contributing to students' development of their overall quantitative skills, and that their experiences engage them with related activities.

Table 5
CSS and NSSE survey responses to questions dealing with gains in quantitative skills

1.Compared to your peers how would you describe your mathematical skills (CSS 2009)?

	La Verne (N = 243)			Non-Sectarian 4-year colleges		
	Total	Men	Women	Total	Men	Women
Highest 10%/Above average	29.3%	42.1%	25.4%	42.6%	54.7%	34.1%

2. To what extent has your experiences at this institution contributed to your knowledge, skills, and personal development in analyzing quantitative problems (NSSE 2010)?

	Freshmen (n = 123)	Seniors (n = 356)	Trad. Senior (n = 90)	Non-trad. Senior (n = 275)
Mean on 4-point scale (4 = Very Much)	3.06 (32% Very Much)	3.25(48% Very Much)*	3.34	3.22*

* P < .01

3. Questions in the NSSE 2.0 2011 beta testing pilot (to be released 2013)

	Freshmen		Seniors	
	N	%	N	%
a. How much has your experiences at this institution contributed to your knowledge, skills, and personal development in analyzing numerical and statistical information (NSSE 2011)? (Quite a bit/ Very much)	147	47%	418	73%

Action Recommendations

1. Revise the rubric to include a zero rating to reflect the complete absence of an attempt to respond to the question, or for having missed the point altogether.

2. Present these findings to the General Education Committee for a discussion of the way Quantitative Reasoning Learning Outcomes are stated, and the criteria for approving courses to meet the GE requirement.

3. Lead a discussion of the faculty who teach the GE Quantitative Reasoning courses to reflect about classroom experiences that relate to the learning outcomes, and about ways of being more explicit in connecting assessments to the GE outcomes.

4. Consider a senior exit exam or a nationally standardized test to assess Quantitative Reasoning skills.

5. Familiarize mathematics tutors at the Learning Enhancement Center with the Quantitative Reasoning Learning Outcomes.

Appendix A

Rubric to Evaluate Quantitative Reasoning Learning Outcome

University of La Verne
G.E. Quantitative Reasoning Rubric

Learning Outcomes	**Accomplished (4)** Accurate and complete or near complete mastery—less than 10% errors in process	**Developed (3)** Competent and proficient—10-20% errors in process	**Developing (2)** Basic skill—20-30% errors in Process	**Undeveloped (1)** Beginning-Below basic skill—greater than 30% errors in process
1. **Represent** mathematical information symbolically, visually, numerically and verbally	**Skillfully converts and represents** relevant information into various mathematical forms or portrayals (e.g. equations, diagrams, graphs, tables, and words) in comprehensible terms that **further or deepen understanding**	**Competently converts and represents** relevant information into various mathematical forms or portrayals (e.g. equations, diagrams, graphs, tables, and words) in mostly appropriate and adequate terms	**Completes conversions** of relevant information into various mathematical forms but resulting portrayals are **only partially appropriate or accurate**	**Completes conversions** of relevant information into various mathematical forms but resulting portrayals are **mostly inappropriate or inaccurate**
2. **Interpret and draw inference** from mathematical models such as formulas, graphs, tables, and schematics	Provides **accurate explanations** of information presented in mathematical forms, and makes **appropriate and insightful inferences** based on that information (e.g. trend data in a graph, and statistical or actuarial significance of findings/data)	Provides **accurate explanations** of information presented in mathematical forms, and **inferences** based on the information are **adequate** (e.g. trend data in a graph, and statistical or actuarial significance of findings/data)	Provides **mostly accurate explanations** of information presented in mathematical forms, and **inferences** based on the information are only **partially adequate**	Provides **partially accurate explanations** of information presented in mathematical forms, and **inferences** based on the information are **inadequate**
3. **Apply** Arithmetical, algebraic, geometric and statistical methods with appropriate technological **tools to solve problems**	**Expertly and accurately** uses arithmetic and algebraic functions with appropriate technological tools to solve problems, and presents calculations **clearly and concisely**	**Accurately** uses arithmetic and algebraic functions with appropriate technological tools to solve problems, and presents calculations **adequately**	**Applies mostly accurate** arithmetic and algebraic functions with appropriate technological tools to solve problems, but presentation of calculations are partially **adequate**	**Applies partially accurate** arithmetic and algebraic functions with mostly appropriate technological tools to solve problems, but presentation of calculations are **inadequate**
4. **Think critically** and apply common sense in estimating and **checking answers** to mathematical problems in order to determine reasonableness, identify alternatives, and **select optimal results**	**Expertly and accurately** uses critical thinking and common sense to **check and verify** the reasonableness and appropriateness of the final answers, identifies alternatives, and selects **optimal results**	**Appropriately** uses critical thinking and common sense to **check and verify** the reasonableness and appropriateness of the final answers, identifies **most** alternatives, and selects **optimal results**	**Occasionally** uses critical thinking and common sense to **check and verify** the reasonableness and appropriateness of the final answers, identifies **few** alternatives, and selects **partially optimal results**	**Does not adequately** use critical thinking and common sense to **check and verify** the reasonableness and appropriateness of the final answers, is **unable** to identify alternatives, and selects **results that are not optimal**