Seaver College General Education (GE) Assessment- Quantitative Reasoning Academic Year 2011-2012

I. Program Learning Outcome

"Students reason and solve quantitative problems and explain mathematical concepts and data."

II. Institutional Educational Outcomes (Objectives)

It is generally accepted that quantitative reasoning, in some form, should play a central role in higher education. At Pepperdine University, we agree with the Association of American Colleges and Universities (AAC&U) that quantitative reasoning should not be defined as a skill or simple ability to solve numerical problems. Rather, quantitative reasoning should be viewed as a habit of mind that allows students to process, analyze, and communicate quantitative information in authentic, everyday contexts.

From this perspective, the general education requirement for quantitative reasoning directly aligns with the Institutional Educational Outcomes of Service and Leadership in the category of Knowledge & Scholarship, as show below:

Knowledge & Scholarship
Service: Apply knowledge to real-world challenges.
Leadership: Think critically and creatively, communicate clearly and act with integrity.

III. Student Learning Outcome(s)

Thinking of Quantitative Reasoning as a "habit of mind" forces us to ask what observable outcomes can be associated with achieving this objective. Since our objective is singular, we have decided to describe it as a singular student learning outcome and describe in detail the elements that compose that singular outcome:

SLO	*"Students will be able to reason quantitatively in order to effectively solve problems and explain mathematical concepts and data in authentic contexts."*

This student learning outcome is highly dependent on the definition of *quantitative reasoning*. We have taken our definition from the AAC&U's VALUE Rubric on Quantitative Literacy. This rubric outlines six observable skills associated with quantitative reasoning:

- The ability to *interpret* information presented in a mathematical form.
- The ability to *represent* information in a mathematical form.
- The ability to effectively *calculate* using quantitative data.
- The ability to *analyze* quantitative information in order to draw appropriate conclusions.
- The ability to make and evaluate the *assumptions* used in analyzing quantitative data.
- The ability to *communicate* quantitative information in support of an argument.

IV. Curriculum Map

Pepperdine University has identified nine courses which satisfy the general education requirement for quantitative reasoning. Because students are only required to enroll in one of these courses, each student should be expected to demonstrate a mastery of basic elements of quantitative reasoning upon exiting the course. That is, the student should demonstrate the ability to *interpret, represent, calculate, analyze, evaluate assumptions, and communicate* quantitative information within accessible contexts for that individual student.

The table below summarizes the courses designed to satisfy the general education quantitative reasoning requirement:

Course	Students will be able to reason quantitatively in order to effectively solve problems and explain mathematical concepts and data.
Math 120	Students will Demonstrate Mastery of the Learning Outcome.
Math 140	Students will Demonstrate Mastery of the Learning Outcome.
Math 141	Students will Demonstrate Mastery of the Learning Outcome.
Math 150	Students will Demonstrate Mastery of the Learning Outcome.
Math 151	Students will Demonstrate Mastery of the Learning Outcome.
Math 250	Students will Demonstrate Mastery of the Learning Outcome.
Math 270	Students will Demonstrate Mastery of the Learning Outcome.
Math 316	Students will Demonstrate Mastery of the Learning Outcome.
Psych 250	Students will Demonstrate Mastery of the Learning Outcome.

V. Assessment Plan

Direct Assessment Plan

Our direct assessment plan is aimed at the goal of gaining a broad picture of our students' quantitative reasoning abilities across all of Seaver College. Therefore, our plan is to collect direct evidence of student learning that represents *every student in every course* designated as satisfying the quantitative reasoning general education requirement.

This broad goal forces us to focus the observable traits of quantitative reasoning being assessed. We have chosen to focus our attention on students' ability to *interpret* and *represent* quantitative information. This decision was made for two reasons:

First, the decision was made out of necessity. The nature of the observable traits of quantitative reasoning necessitate that students first be able to interpret and represent quantitative information before they can achieve the other observable traits. For example, a student must be able to represent quantitative information before he/she can effectively calculate using those representations, and a student must first be able to interpret quantitative information before he/she can analyze the information in order to draw conclusions.

Second, the decision was made out of experience. Those involved in the assessment shared the experience that students tend to struggle with the interpretation and representation aspects of problem solving. We believe these struggles are in part responsible for students' aversion towards "word problems" and other attempts at bringing authentic situations into the classroom. This is supported by research literature including Smith and Thompson (2007) who observed that many of the algebraic struggles that students in their study encountered were due to constructing incorrect mental images while orienting to the problem.

The broad goal of assessing every course created a challenge of comparing results across courses which cover very different material in order to draw broad conclusions. In order to achieve this we chose to focus our assessment on general questions involving contexts of which all Pepperdine Graduates could be reasonably expected to be familiar. The quantitative reasoning assessment team met several times over the fall and spring semesters and created a short assessment of six items that we felt focused on the interpretation and representation of quantitative data and which used no specialized mathematics not contained in all of our courses.

Direct Assessment Items

The six assessment items created by the committee (available in Appendix A) can be summarized as covering the following content:

Problem	**Content**
#1	Logically interpret a statement given in “if – then” form.
#2	Logically interpret a statement given in “if – then” form.
#3	Interpret an accumulated amount given in a pie chart.
#4	Represent graphically an accumulated quantity given in a pie chart.
#5	Compare two rate-of-change graphs across an interval.
#6	Compare two rate-of-change graphs at a point.

The problems in the assessment were written in pairs in order to better identify consistency in student errors and identify misconceptions leading to incorrect responses.

Indirect Assessment Plan

Our indirect assessment plan aimed to create a picture of student’s attitudes and beliefs about quantitative reasoning across Seaver College. For this reason, targeted questions were placed on the Seaver College Senior Survey to determine graduating seniors’ perceptions of the quantitative reasoning portion of the GE requirement.

VI. Rubrics

The quantitative reasoning assessment committee met to determine how to interpret student scores on the direct assessment. It was agreed upon that scores would be interpreted as:

5 – 6 Problems Correct	High Level of Quantitative Literacy
3 – 4 Problems Correct	Medium Level of Quantitative Literacy
0 – 2 Problems Correct	Low Level of Quantitative Literacy.

VII. Criteria for Student Achievement / Success

Based on our interpretation of the scores, we set the following benchmarks for determining a low level of success, a preferred level of success and an aspirational level of success as shown in the table below:

Level of Success	Low	Preferred	Aspirational
Students Performing at a High Level of Quantitative Literacy	10%	20%	50%
Students Performing at or above a Medium Level of Quantitative Literacy	60%	80%	90%
Cumulative Average	2.75	3.5	4.25

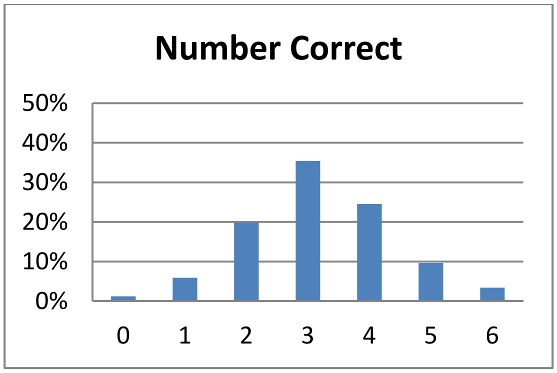
VIII. Evidence / Data

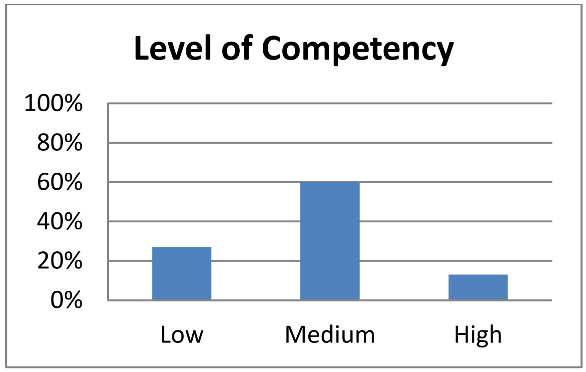
Overview of the Direct Assessment Data:

The assessment took place during the final two weeks of class in the Spring 2012 semester. 322 students completed the assessment, representing 76% of all students originally enrolled in a quantitative reasoning GE course for Spring 2012. The figures for specific courses are given in the table below:

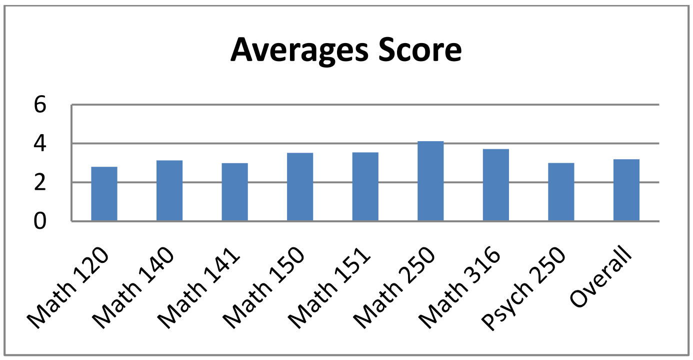
Course	Participants	Percent
Math 120	61	88%
Math 140	39	53%
Math 141	91	83%
Math 150	25	61%
Math 151	13	81%
Math 250	25	93%
Math 316	28	78%
Psych 250	40	75%
Overall	**322**	**76%**

Overall 13% of the students taking the exam demonstrated a high level of quantitative literacy and 60% of the demonstrated a medium level of quantitative literacy for a total of 73% of the students demonstrating a medium or high level of quantitative literacy. These results fall below our preferred level of success for students performing at a high level of quantitative literacy (preferred 20%) and students performing at or above a medium level of quantitative literacy (preferred 80%). The charts on the next page depict the percentage of students achieving different scores on the exam.





The average score of all participating students was 3.19 which falls below our preferred level of success by 0.31 points. Out of the eight courses involved in the assessment, four achieved an average score at the preferred level of success while four achieved an average score at a low level of success.



Overview of Indirect Assessment Data

All graduating seniors at Seaver College were asked to complete a survey indicating the way in which the general education program contributed to their knowledge. Question 13 on this survey related directly to quantitative reasoning and was worded as:

How has the General Education curriculum contributed to your knowledge, skills and personal development in the following areas:

13. Quantitative Reasoning: Explain math concepts, solve quantitative problems, and understand empirical data.

272 students responded to this question and their responses are summarized below:

Very Little	Somewhat	Sufficiently	Considerably
26.8%	29.4%	30.5%	13.2%

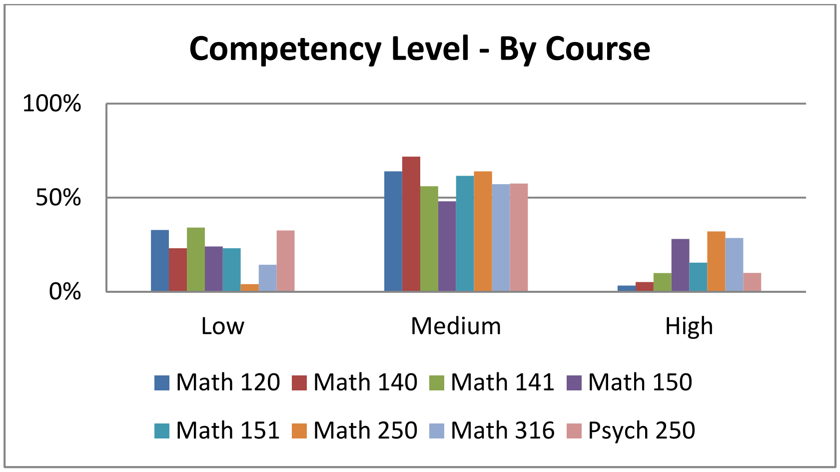
Evaluating these results using a Likert Scale (1 – Very Little, 4 – Considerably), the Quantitative Reasoning GE averaged a score of 2.30. In comparison with the other 22 GE areas assessed on this survey, the Quantitative Reasoning GE received the lowest Likert score, with the average score being 0.33 points behind the overall average of 2.63 for all 22 items.

IX. Summary

The Quantitative Reasoning GE Assessment Committee agreed that the students involved in our assessment achieved below our expectations. At the same time, the committee recognizes the danger in drawing broad conclusions based one assessment. Committee members identified several features of the assessment which could have contributed to lower than expected scores, including: the potentially misleading wording of items 1 and 2, student investment in the exam due to lack of grade implications, prior knowledge of the students, and the general lack of data due to the scale (only 6 questions) of the exam. Therefore, we believe the true value of the assessment is not in judging the competency of our graduates but instead in creating a roadmap for further investigation.

Comparison of Performances by Course

Each of the courses involved in the assessment were compared with the percentage of students performing at each competency level displayed on the following chart.



Looking through the data, there seemed to be a clear distinction between the performance of students in courses taught primarily for natural science majors (Math 150, Math 151, Math 250, and Math 316) and courses taught primarily for non-natural science majors (Math 120, Math 140, Math 141, and Psych 250). This is illustrated in the following table:

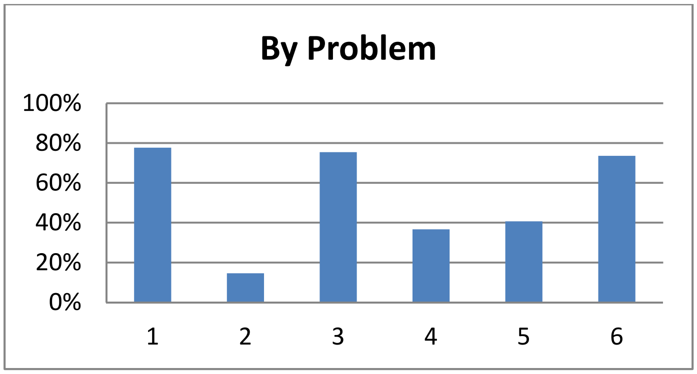
	Students Enrolled	% Achieving at least Medium Competency	% Achieving High Competency	Average Score
Math150/Math151/Math250/Math316	91	85%	27%	3.75
Math120/Math140/Math141/Psych250	231	68%	7%	2.97

This table indicates that either through prior experience, self-selection, or course instruction students enrolling in mathematics courses designed for natural science majors tended to perform at a preferable level of quantitative reasoning ability. However, due to the same potential factors, students enrolled in quantitative reasoning courses designed for non-natural science majors overall failed to perform at a preferable level of quantitative reasoning.

For these reasons, the areas in greatest need of improvement are the courses designed for non-natural science majors. We intend, in the short term, to focus our attention and efforts towards determining ways in which the students enrolled in these courses can improve their quantitative reasoning abilities.

Comparison of Student Performance on Individual Items

The problem-by-problem performance of all students involved in the assessment is summarized in the following chart:



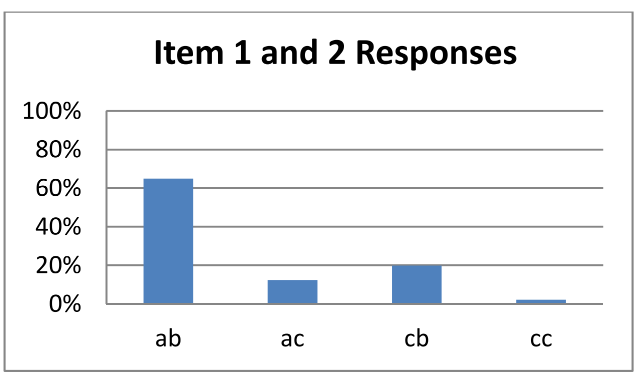
From these results we see that students performed the worst on items 2, 4, and 5. Therefore, we will take a closer look at these specific items.

Item 2

Items 1 and 2 were written to determine students' abilities to interpret information given in the form of an if-then statement. Item 1 assumes the hypothesis to be true while item 2 assumes the hypothesis to be false.

The committee, while discussing the low scores on item 2, determined that there are several confounding factors that could have misled students. In particular, the wording of the problem as well as students' experiences with the context (a purchasing contract) might have misled students into the interpreting the if-then statement as one of many requirements the purchaser must meet. However, it was also noted that this perspective would likely have led the student to miss item 1 as well.

A comparative summary of all responses to items 1 and 2 is located in the following chart:



The above chart indicates that roughly 20% of the students possibly interpreted the statement to mean the converse of its actual meaning; whereas, over 60% of the students interpreted the statement as an if-an-only-if statement.

Additionally, students' performance on item 2 was correlated with their performance on the remaining problems. Students who correctly answered item 2 achieved a mean score of 3.47 on the remaining 5 problems while students who incorrectly answered item 2 achieved a mean score of 2.97 on the remaining 5 problems. This indicates that the ability to read and interpret logical statements is correlated with the ability to interpret quantitative data in other forms.

For these reasons, we would like to gather more data on students' abilities to read and interpret logical statements. In particular, we would like to know how to improve our instruction to support students' development in this area, whether improved abilities in the context of our courses are translated to situations outside of our classes, and whether these abilities influence students' performance on other quantitative assessments.

Items 4 and 5

Items 3 and 4 were written to determine students' abilities to interpret information given on a chart and emphasized interpreting an amount from a percentage and the concept of accumulation.

One of the hallmarks of quantitative thinking is the ability to focus attention on appropriate quantities. In this respect, the students involved in the assessment performed exceptionally well as 89% of the students gave a response to item 3 that indicated that they were attending to the number of adults (and not the percentage) and 81% of students gave a response on item 4 that indicated that they were attending to the number of adults.

We found it interesting that overall students were successful at applying the concept of accumulation on item 3, as 75% answered that item correctly; whereas, the students struggled in applying the concept of accumulation on item 4 with only 37% answering that item correctly. At the same time, on item 4, 44% of the students responded with (d) which indicates that they were attending to the correct quantity but not applying the concept of accumulation.

Items 5 and 6 were written to determine students' abilities to interpret information given on a graph and emphasized the concept of rate of change.

Students involved in the assessment were much more successful on item 6, answering that problem correctly 74% of the time as compared to item 5, which they answered correctly only 41% of the time. The most popular pair of responses were (c) on item 4 and (a) on item 5 which was given by 35% of the students. This can be compared to the correct pair of responses which was given by 28% of the students and the responses (c) and (b), which would indicate that the students interpreted the graph as being of the distance travelled (rather than the velocity) which was given by 11% of the students.

The committee observed a commonality between the results on items 3 – 6 in that students performed well on items 3 and 6 which required the students to reason about a single value on the chart and the graph and struggled with items 4 and 5 which required the students to reason across values throughout the chart and graph. This struggle has been identified in mathematics education literature and often attributed to students' inabilities to coordinate the behavior of two quantities simultaneously (Carlson, et al., 2002, Thompson, 2008). The committee would like to investigate methods for improving this coordinating ability among students and assess the success of these methods.

Indirect Evidence

Indirect evidence collected from the senior survey indicated that less than half the students (43.7%) identified the GE program as either "successfully" or "considerably" contributing to their knowledge of quantitative reasoning. Coupling this with the fact that quantitative reasoning was the lowest scoring GE outcome on the survey indicates a gap between the GE programs' goals of quantitative reasoning and the students' experiences in the GE program.

The committee discussed this gap and believed that these results might indicate a disconnect for students between their math courses and the rest of their academic program. The committee would like to investigate this possibility in future indirect assessments.

X. Closing the Loop & Quality Improvement Program

The committee feels that it would be unwise to radically modify the Quantitative reasoning GE Program based on the results of a single six-question assessment. Therefore, our primary recommendation is to look closely at specific weaknesses identified in the assessment in order to better determine the cause of the weakness and potential avenues for improvement. This assessment has brought two such weaknesses to our attention: Reading and interpreting logical statements and coordinating quantities throughout an interval. We would like to follow a lesson study methodology, where members of the committee collaborate in developing a lesson to emphasize concepts in which students struggle followed by an analysis of the student responses to the lesson. This recommendation will manifest itself in the two upcoming assessment cycles, and are summarized as the Action Items #1 and #2 below:

- **Action Item #1**: Investigate Student Understanding of Logical Statements
- **Evidence to support this proposed action:** Results from Item 2 in the Direct Assessment
- **Expected outcome (if the action item is implemented):**
  Faculty will gain insight into how we may improve students' abilities to read and interpret logical statements.
- **Expected timeline:** Academic Year 2012-2013
- **Type of Action:** ☒ **Resource Neutral** ☐ **Resources Required**

- **Action Item #2**: Investigate Student Understanding of How Quantities Are Coordinated throughout an interval.
- **Evidence to support this proposed action:** Results from Items 4 and 5 in the Direct Assessment
- **Expected outcome (if the action item is implemented):**
  Faculty will gain insight into how to improve students' abilities to coordinate several quantities across a continuum of values.
- **Expected timeline:** Academic Year 2013-2014
- **Type of Action:** ☒ **Resource Neutral** ☐ **Resources Required**

XI. Contributors

Assessment of this area of the General Education program was performed by the following individual(s).

Committee Chairperson	Position Title	Academic Division
Brian Fisher	Assistant Professor of Mathematics	Natural Science

Committee Members	Position Title	Academic Division
Carol Adjemian	Professor of Mathematics	Natural Science
Don Hancock	Professor of Mathematics	Natural Science
Kevin Iga	Professor of Mathematics	Natural Science
Timothy Lucas	Assistant Professor of Mathematics	Natural Science
David Strong	Professor of Mathematics	Natural Science
Don Thompson	Professor of Mathematics	Natural Science

APPENDICES

Appendix A - Assessment Details

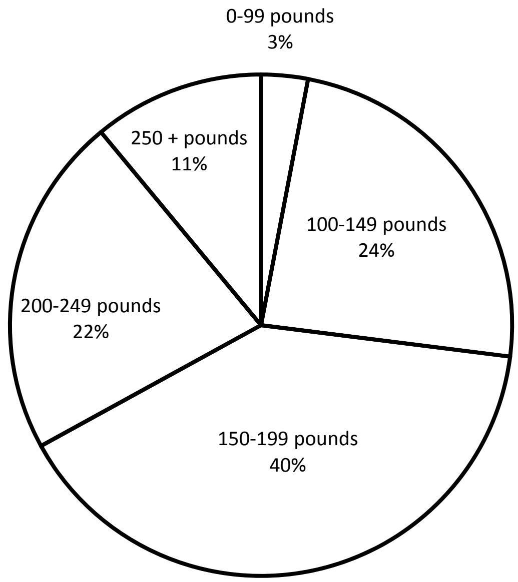
The following problems were used for direct assessment of the student learning outcome.

Clayton is hoping to buy car insurance from a discount insurance company. The language in the contracts reads as follows:
"If you are over 21 years old and have not been in an accident in the past year then you are eligible to purchase insurance."
Clayton has not been in an accident in the past year. Please answer the following questions.

1. ______ If Clayton is over 21 then
   a) He is definitely eligible to purchase insurance from this company.
   b) He is definitely ineligible to purchase insurance from this company.
   c) He could be either eligible or ineligible depending upon other company requirements.

2. ______ If Clayton is under 21 then
   a) He is definitely eligible to purchase insurance from this company.
   b) He is definitely ineligible to purchase insurance from this company.
   c) He could be either eligible or ineligible depending upon other company requirements.

200,000 adults were surveyed about their weight with the results displayed on the chart to the right:

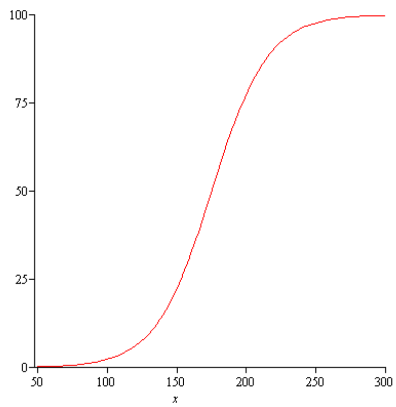


3. ______ Approximately how many of the adults surveyed weigh less than 150 pounds?

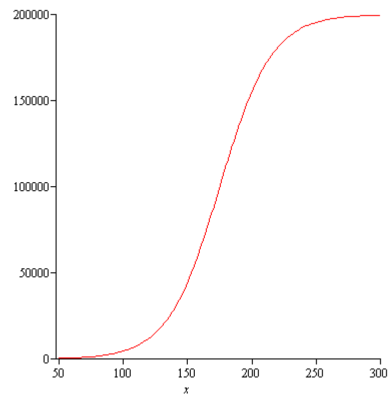
a) 24,000
b) 27,000
c) 48,000
d) 54,000
e) None of the above

4. ______ Which graph below might reasonably represent the total number adults surveyed whose weight is less than *x* pounds?

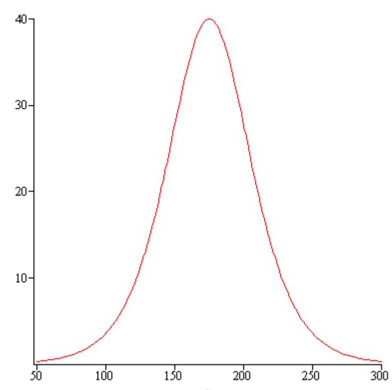
a)



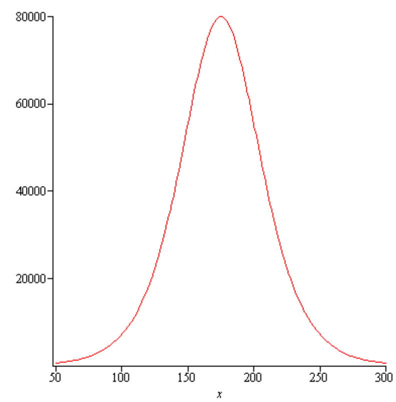
b)



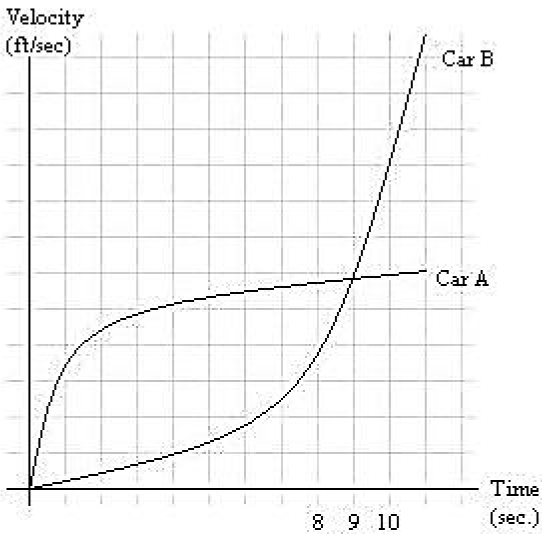
c)



d)



Two cars, Car A and Car B, speed up from a stoplight. The velocities of the two cars are recorded on the following graph.



5. _____ Which car travels further during the first 9 seconds after the light turns green?
   a) Car A
   b) Car B
   c) They travel the same distance
   d) It is impossible to tell from this graph
6. _____ Which car is traveling faster 8 seconds after the light turns green?
   a) Car A
   b) Car B
   c) They are traveling at the same speed
   d) It is impossible to tell from this graph

Appendix B - Chronology

The committee met and performed activities in support of this assessment as indicated below.

Date	Members Participating (Initials)	Action
10/27/2011	CA, BF, DH, TL, DS, DT	Discussed Program Learning Outcome and Student Learning Outcome
11/17/2011	CA, BF, DH, TL, DS, DT	Discussed Student Learning Outcome and possible assessment plans
12/3/2011	CA, BF, DH, TL, DS, DT	Finalized Student Learning Outcome and discussed possible assessment plans
1/19/2012	CA, BF, DH, KI, TL, DS, DT	Discussed assessment plans
2/2/2012	CA, BF, DH, KI, TL, DS, DT	Finalized assessment plan
2/23/2012	CA, BF, DH, KI, TL, DS, DT	Discussed direct assessment items
3/8/2012	CA, BF, DH, KI, TL, DS, DT	Finalized direct assessment items
3/29/2012	CA, BF, DH, KI, TL, DS, DT	Finalized implementation of direct assessment items
4/26/2012	CA, BF, DH, KI, TL, DT	Discussed results of direct assessment and created action items based on the results
5/15/2012	CA, BF, DH, KI, TL, DS, DT	Over email the committee reviewed and edited the final assessment document

References

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Smith, J., & Thompson, P. W. (2007). Quantitative reasoning and the development of algebraic reasoning. In J. Kaput, D. Carraher, & M. Blanton (Eds.), *Algebra in the early grades* (pp. 95-132). New York: Erlbaum.

Thompson, P. W., & Silverman, J. (2008). The concept of accumulation in calculus. In M. Carlson & C. Rasmussen (Eds.), *Making the connection: Research and teaching in undergraduate mathematics* (pp. 117-131). Washington, DC: Mathematical Association of America.