Assessing Quantitative Reasoning: EVALUATE What Students Know

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QLP Technical Report: QLP-TR 2012-001

Presented at the Joint Statistical Meeting 2012 in San Diego, California

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Abstract
Developing effective assessments of quantitative reasoning (QR) has posed a major challenge to the academic community. Even though there is a significant amount of literature on development of instruments for assessment of mathematical skills the research on assessing QR has been rather limited. One of the main challenges is that quantitative reasoning skills are, by definition, rooted in context. The University of Texas at San Antonio has developed a program to integrate quantitative reasoning skills across various disciplines in the general education curriculum. To assess and evaluate different levels of student learning, the taxonomy of Bloom and Webb was used to identify a list of action verbs associated with a basic, intermediate, and advanced level of cognition of QR. This process has allowed for student performance data to be collected and tracked longitudinally. In this article, an example of the student learning outcomes and course embedded assessment is presented for one of the general education courses participating in the program.

Keywords: Quantitative Literacy, Assessment, Taxonomy

1. Introduction

"*Quantitative literacy is more a habit of mind……numeracy is often anchored in data derived from and attached to the empirical world."* The Carnegie Foundation [1]

Quantitative reasoning skills are critical, not only in the workplace, but in everyday life. These skills play an important role in understanding, analyzing, interpreting, communicating, and presenting data. It is valuable to understand data in order to make important, meaningful decisions. When asked to describe quantitative literacy, a quality manager characterized it as *"the ability to conceptualize work, identify metrics for gathering data, and understand how to utilize data to take action to improve performance."* [2]

The University of Texas at San Antonio (UTSA) realizes the growing need for its graduates to be quantitative literate in this data-driven society. In 2008, UTSA embarked on an ambitious program to integrate quantitative reasoning skills in courses that are part of the general education curriculum. The program, **Quantitative Scholarship: From Literacy to Master,** seeks to prepare students to successfully use quantitative reasoning in their personal and professional lives. [3]

Assessment is a crucial link between the student and the professor, and provides a formal setting for the evaluation of learning. It allows for the students to receive feedback by identifying the outcomes they have mastered, and targeting areas that need improvement. It establishes a way for an institution to track the progress of student learning and progress toward program goals.

The University of Texas at San Antonio has developed a program to assess quantitative literacy across multiple disciplines in the general education curriculum. These disciplines vary from those that are already data intensive, such as Biology and Astronomy, to others which do not generally work with data, such as Sociology. The program has defined clear goals and student learning outcomes (SLOs) designed to measure and assess a student's understanding of quantitative literacy and communication skills.

The first section of this paper will define the Quantitative Literacy Program's (QLP) student learning outcomes. The second section introduces the tools needed to assess the SLOs at different levels of understanding (taxonomy). Section 3 will describe the need and use of the taxonomy levels based on the work of Webb and Bloom [4], to develop a common framework of assessment across all disciplines. Finally, a discussion of challenges faced while integrating quantitative reasoning into the general education courses will be discussed.

2.1 EVALUATE

The overarching goal of the Quantitative Literacy Program is to instill quantitative reasoning and communication skills in students. In order to meet this goal, three student learning goals have been defined

Student Learning Goal I: The program will help undergraduate students acquire basic quantitative literacy and numeracy skills (Quantitative Literacy).
Student Learning Goal II: The program will help undergraduate students effectively communicate results of their quantitative analysis in writing or by other means. (Communication)
Student Learning Goal III: The program will help undergraduate students acquire discipline-specific advanced quantitative skills (Quantitative Mastery). [3]

This paper will focus on measuring student learning goals I and II, Quantitative Literacy and Communication. The program tracks a student's ability to understand, analyze, and interpret data, and communicate the results. Baseline data is collected through the Quantitative Literacy Assessment Test (QLAT), an instrument created by a group of UTSA faculty. The QLAT is administered to all incoming freshman and transfer students at the University.

The implementation of the QL Program included a call for proposals from departments seeking to enhance their general education courses through the integration of QR skills. The cohort of faculty teaching these courses attend a training workshop that helps them develop course-embedded assignments, projects, quizzes, pre and post tests, and/or exams that relate specifically to QR. Participating faculty members are required to report item level student performance for each student learning outcome. An exit test will also be administered to every student at the time of graduation.

All these different assessments that have been developed must have common goals and outcomes to allow progress to be measured within and across courses. In other words, the questions that are related to quantitative reasoning need to be assessed in a way that can be generalized across any discipline. Eight student learning outcomes EVALUATE have

been created that address different facets of QR. Each letter of EVALUATE describes what students should know about quantitative reasoning:

1. ***Explore***: define a problem, identify measurements, develop a plan
2. ***Visualize***: identify patterns and characteristics of visual representations of data, construct tables, charts, and graphs
3. ***Assimilate***: compare and contrast two representations of the same dataset, or two different methods of data analysis
4. ***Logic:*** compute and interpret probabilities, evaluate risk
5. ***Understand:*** identify scales of measurement, perform conversions, recognize sampling, bias, validity, and reliability
6. ***Analyze:*** compute and interpret basic numerical summaries and use appropriate quantitative methods to draw conclusions
7. ***Translate:*** make correct and meaningful verbal assertions about data, transform verbal assertions into quantitative expressions
8. ***Express:*** write short summaries about data, communicate results of data analysis, write reports based on a complete quantitative analysis

Courses are required to address a minimum of four student learning outcomes and must include the two outcomes related to communication: Translate and Express, in the first stage of implementation.

The QLP team developed and provides faculty with tools for measuring student performance of quantitative reasoning skills. The Basic, Intermediate, and Advanced levels of skill/taxonomy are based on Bloom and Webb's Taxonomy [4]. Taxonomy levels have been created to assess student progress for each of the eight student learning outcomes of the QLP. Action verbs have been associated at each level of the eight student learning outcomes.

	Basic	Intermediate	Advanced
Explore	Define Identify	Organize Collect	Formulate Design Investigate
Visualize	Tabulate Rank Identify	Create Graph Construct	Display
Assimilate	Compare Associate	Contrast Distinguish	Synthesize
Logic	Calculate	Interpret	Argue
Understand	Convert Identify	Recognize	Critique Apply Argue
Analyze	Calculate	Implement	Investigate Predict
Translate	Define State	Summarize Paraphrase	Transform
Express	Describe List	Report	Argue

Courses that been selected for course redesign (Q-courses) are encouraged to utilize these action verbs when addressing various quantitative reasoning outcomes. During its first year of implementation, the following ten courses were selected for the program:

- Introduction to Physical Anthropology
- Introduction to Archaeology
- Introduction to Astronomy
- Contemporary Biology
- Biosciences I
- Economic Principles and Issues
- Introductory Microeconomics
- Introductory Macroeconomics
- Geology: The Third Planet
- Introduction to Sociology

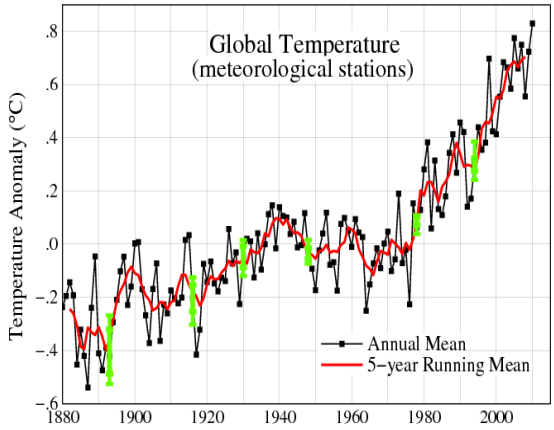
In the second year of the program, six additional courses were chosen for course redesign.

- Algebra for Scientists and Engineers
- Introduction to American Politics
- Basic Chemistry
- English Composition I and II
- Basic Statistics
- Introduction to World Civilizations to the 15th Century

2.2 Example

An example will be used to illustrate how the eight student learning outcomes can be addressed in a course assignment. This particular assignment, addresses the influence of human actions on global climate.

Scenario: The following graph obtained from the NASA Goddard Institute for Space Studies web site depicts global temperature changein °C since the year 1880. The units shown are departures from the mean of the 1951-1980 periods. The dotted black line is the annual mean and the solid red line is the five-year mean. The green bars show uncertainty estimates.The table provides the temperature anomalies for Global, Northern and Southern hemispheres for the period 1981-2000. [5]



Year	Glob	NHem	SHem	Year	Glob	NHem	SHem
1981	0.26	0.33	0.18	**1991**	0.35	0.37	0.32
1982	0.04	0.01	0.07	**1992**	0.13	0.07	0.18
1983	0.25	0.2	0.29	**1993**	0.13	0.15	0.12
1984	0.09	-0.01	0.18	**1994**	0.23	0.33	0.14
1985	0.04	-0.05	0.14	**1995**	0.37	0.53	0.21
1986	0.12	0.09	0.15	**1996**	0.29	0.25	0.32
1987	0.27	0.21	0.32	**1997**	0.39	0.49	0.29
1988	0.31	0.31	0.32	**1998**	0.56	0.7	0.43
1989	0.19	0.22	0.16	**1999**	0.32	0.47	0.16
1990	0.36	0.48	0.24	**2000**	0.33	0.48	0.19

1. For the five-year period 1995-1999, determine the average temperature change for the Northern Hemisphere
2. Determine whether the following statements are true or false.

    a. In 1998, the mean temperature for the Northern Hemisphere was 0.7°C above the 1951-1980 average.
    b. Since 1991, global mean temperatures have shown an increasing trend.
    c. The greatest temperature anomalies have typically occurred in the Northern Hemisphere.
    d. Since 1981, mean temperatures in both hemispheres have been above the 1951-1980 average.
3. Analyze the temperature data for the Northern and Southern hemisphere since 1981. Compare the trends to the global trend.
    a. Identify the three warmest years on record.
    b. Write a short summary of your findings and include appropriate summary data from the charts.
4. Download CO_2 data from the NOAA website for the 1981-2000 period.
5. Is there evidence to suggest an association between CO_2 levels and temperature change? Write a short summary to defend your conclusion. Include appropriate graphs, tables and summary data to support your argument.

Question 1 asks the student to calculate an average temperature. This requires a basic computation of a numerical summary, which would fall under the QLP student learning outcome *Analyze (Basic)*. In Question 2, students research several statements written about the data to determine which ones are correct. This relates to student learning outcome *Translate (Basic)*. The first part of Question 3 asks a student to look at a visual representation of the data and identify importation characteristics. This is an example of the Student Learning Outcome *Visualize* at a *Basic* level of understanding. However, in the second part of the Question, students are then asked to summarize the data, indicating the QLP student learning outcome *Translate* at an *Intermediate* Level. The last two questions require students to physically collect data from a website, indicating the QLP student learning outcome *Explore* at an *Intermediate* level. Then, determine if an association exists requiring a student to defend their results of a quantitative analysis indicating the QLP student learning outcome *Express* at an *Advanced* level of taxonomy.

The datasetcould be used through the semester to introduce more advanced QR skills.

2.3 Challenges

Integrating quantitative literacy across multiple disciplines has been a challenge. Quantitative literacy *can* be assessed with multiple choice questions at basic levels of understanding. However, eventually students are required to communicate through writing. Writing is almost always met with trepidation by both students and faculty-especially with large classes. Assessing writing requires well defined rubrics to minimize variability in scores. In small classes, professors can create extensive projects requiring the students to physically collect data, analyze various quantitative questions, and then provide a written report of their data analysis. Some even require oral presentations. However, in large classes, writing is kept to a minimum. Students are asked to communicate their understanding in just a few sentences. Various techniques can be used such as asking the student to provide bullet points, write 1-minute papers, journal entries, or lists. [6] Professors can give guided questions to include key points such as:

- **Who**?
  - Who designed the experiment?
  - Who conducted the survey?
  - Who funded the project?
- **What**?
  - What are the study characteristics?
  - What is the population of interest?
  - What are the variables of interest?
- **When**?
  - When was the study conducted? Specify the time frame.
- **Where**?
  - Where was the data collected? Location.

3. Conclusion

The University of Texas at San Antonio is currently in Phase II of the QLP implementation. Every course designated as "Q" will be required to extend embedded Q-assignments into all course sections and provide a method for sustainability. A longitudinal study will effectively determine the impact of quantitative reasoning across the core curriculum. Preliminary feedback from students and faculty has been positive.

4. References

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