

Assessing Quantitative Reasoning: What do Freshmen Know?

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Abstract

The University of Texas at San Antonio (UTSA) is one of the fastest growing public universities in the state with a student population that includes a large number of historically underserved students. UTSA has developed a comprehensive plan to integrate quantitative reasoning across the core curriculum. An instrument was developed to assess the baseline quantitative literacy levels of incoming freshmen. Items on the instrument test a student's working knowledge of simple probability, interpreting data summaries, and interpreting graphs and charts. Items on the instrument map to well-defined quantitative learning outcomes. Student performance on the instrument is grouped into three categories; at or below basic, intermediate, and proficient. Comparisons across gender and ethnicity will be discussed. In addition, performance on the assessment will be compared to student performance on SAT, ACT and Math placement tests. Results of the instrument will provide item level data which will allow for longitudinal assessment during the student's program of study. The results of a confirmatory factor analysis will be presented.

Key Words: Quantitative literacy, assessment, curriculum development

1. Introduction

The first page of the book *Mathematics and Democracy* [1] starts with the thought-provoking statement: “*The world of the twenty-first century is a world awash in numbers.*” Recent advances in technology, particularly the Internet have resulted in an unprecedented explosion in the amount of information and data. According to an article in the *New York Times* [2], the research firm IDC predicts that the amount of digital data will rise fivefold by 2012. Every single day, we are inundated with information and data: number of H1N1 deaths, unemployment numbers, cost of health care reform, and effectiveness and safety of new drugs. The skills needed to understand, interpret, and evaluate real data to make informed decisions are critical to empowering all citizens and enriching their personal and professional lives.

In 1998, the Mathematical Association of America’s Committee on the Undergraduate Program (MAA-CUPM) published a report [3] that provided a set of quantitative literacy requirements for all undergraduate students. In the report, the committee stated

“Colleges and universities should treat quantitative literacy as a thoroughly legitimate and even necessary goal for baccalaureate graduates.”

Over the last decade, quantitative literacy has been recognized as critical to the survival of democracy. A national conversation [1], [4] has begun on how schools and colleges can effectively implement programs that help their students succeed in the global economy. With this increasing awareness of the critical need for quantitative literacy, many universities have developed programs to embed quantitative methods and technology in courses in the arts and the humanities. The websites <http://www.statlit.org> and <http://www.stolaf.edu/people/steen/Papers/qlprogs.pdf> provide a list of institutions that have implemented quantitative literacy/quantitative reasoning programs.

1.1 What do students know? National Data

In spite of this national debate on the importance of quantitative reasoning, studies show that, unfortunately, a large percentage of college graduates struggle to solve real-world problems that require basic quantitative literacy skills. In 2006, the American Institutes for Research (AIR) published a report [5] based on the *National Survey of America's College Students* (NSACS). The survey of 1,827 graduating students from 80 randomly selected two-year and four-year public and private colleges and universities provided a comprehensive assessment of fundamental college literacy. The instrument used in the NSACS was the same as that used in the National Assessment of Adult Literacy (NAAL) study. The NAAL instrument was developed and administered by the U.S. Department of Education's National Center for Education Statistics (NCES), and it is the most comprehensive measure of adult literacy in the United States.

The NSACS measured literacy along three dimensions: prose literacy, document literacy, and quantitative literacy. The following definition of Quantitative Literacy was used:

***Quantitative Literacy:** The knowledge and skills required to perform quantitative literacy tasks, i.e., to identify and perform computations, either alone or sequentially, using numbers embedded in printed materials. Quantitative examples include balancing a checkbook, figuring out a tip, completing an order form, or determining the amount of interest on a loan from an advertisement.*

Key findings from the AIR study revealed that college students struggled most with quantitative literacy. The study found that 20% of U.S. college students completing four-year degrees, and 30% of students earning two-year degrees possessed only basic quantitative literacy skills. They were unable to estimate if their car had enough gasoline to get to the next gas station or calculate the total cost of ordering office supplies. The study also found that 82% of students at two-year colleges and 66% of students at four-year colleges did not score at the proficient level of quantitative literacy. They lacked the skills to perform complex tasks, such as interpreting a table about blood pressure, age, and physical activity; comparing credit card offers with different interest rates; or comparing viewpoints in newspaper editorials.

The data also showed persistence of disparities in the average literacy of White students compared with the literacy of students from other racial/ethnic backgrounds. The study

found that the average prose and quantitative literacy of White students in four-year institutions was higher than for any other racial/ethnic group (Black, Hispanic, Asian). However, differences in the average prose, document, and quantitative literacy of males and females were not statistically significant. Students in four-year institutions who took either a remedial English or math class had lower quantitative literacy scores than their peers who were not required to take a remedial course.

1.2 The UTSA Story

The University of Texas at San Antonio (UTSA) is the second-largest component in The University of Texas System and one of the fastest growing public universities in the state. UTSA embraces the multicultural traditions of its diverse population and serves as a catalyst for socioeconomic development in the region. Enrollment at UTSA has steadily increased over the year with more than 31,000 students enrolled in Fall 2011. Classified as a Hispanic and Minority-Serving Institution, UTSA provides access and opportunity for large numbers of historically underserved students, many of whom are the first in their families to attend a university.

More than 54% of UTSA students come from groups underrepresented in higher education, including 44% Hispanics and 10% African Americans. UTSA ranks fourth overall in the total number of undergraduate degrees awarded to Hispanics in the United States, 12th for Master's degrees, and 22nd for Doctoral degrees.

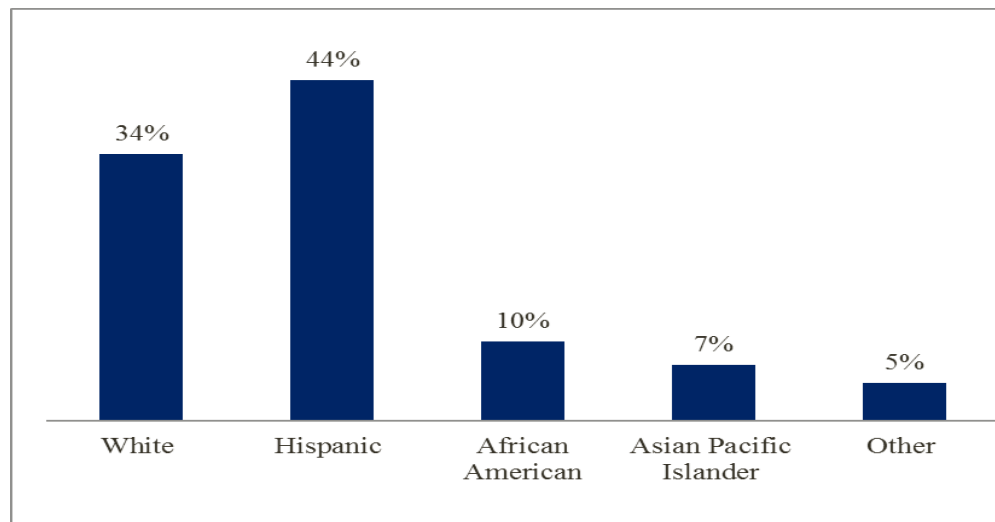


Figure 1: UTSA Freshman Student Population: Fall 2010

At UTSA, all baccalaureate students are required to complete 42 hours of core (General Education) courses divided into six domains. The Mathematics requirements may be satisfied by choosing either College Algebra or Basic Statistics. However, a large number of students do not have the prerequisites to enroll directly into these courses and are placed in developmental courses. Over the past five years, the percentage of students enrolled in remedial mathematics courses has ranged from 36% to 41%. In addition, the performance of students in freshmen level Mathematics and Statistics courses indicates a deficiency in basic mathematical skills. In addition, the percentage of students receiving

grades of D, F, and W (withdraw) in College Algebra and Basic Statistics has ranged from 25% to 39%. No historical data is available that directly measures the level of quantitative literacy of the student population.

These disturbing trends led a group of faculty members from across the University to develop a program to integrate quantitative reasoning skills in courses in the core curriculum. This program was selected as UTSA's Quality Enhancement Plan, a requirement for the accreditation process conducted by the Southern Association of Colleges and Schools. The program *Quantitative Scholarship: From Literacy to Mastery* provides the organizational framework and resources to fundamentally transform the institutional environment to one where quantitative reasoning skills are ingrained in the curriculum and the culture of UTSA.

In the next section, we provide the background for the baseline instrument.

2. Background

2.1 The Instrument

The Quantitative Literacy Assessment Test (QLAT) was developed by a group of UTSA instructors. The goal was to assess what freshmen know about reading and interpreting basic graphs, charts, and tables, simple probability calculations, interpreting data and simple data summaries, and understanding sampling and bias.

The instructors were from various fields of study, including Biology, Computer Science, Management and Marketing, and entry level and upper level Statistics; almost all of them have been teaching for ten to twenty years. Those who have worked in industry contributed valuable information on what students should know in order to remain competitive in a rapidly changing work environment.

The piloted version of the QLAT was administered during the spring of 2009 to first year statistics courses and one bio-statistics course. These classes were filled with only a small percentage of freshmen. Traditionally more than seventy percent of the students are juniors and seniors. Students were encouraged to do well and told their performance would not affect their grade. The pilot QLAT originally had 15 multiple choice questions involving graphs, charts, simple probability, and sampling bias. The team agreed the QLAT had to be non-discipline specific and avoid statistical jargon. For example, we chose relationship over correlation, variability instead of variance or standard deviation, and subject group instead of sampling group. Students were given 20 to 30 minutes to take the QLAT and most finished within 10 minutes. Piloted questions were reworked, graphs were redrawn, and multiple difficulty levels were introduced to accommodate Webb and Bloom's taxonomy levels http://dese.mo.gov/divimprove/sia/msip/DOK_Chart.pdf. A final version of 20 questions was administered to a stratified sample of one thousand incoming freshmen during the summer of 2009. To date, the testing center has administered the QLAT to over 8,000 students. The test is currently administered by the testing

center during freshmen orientation. All materials are provided by the testing center, student identifications are checked, and all electronic devices are secured.

Eight Student Learning Outcomes (SLOs) have been identified as what students should know about quantitative reasoning. Students will be able to **EVALUATE** data:

1. ***Explore* defines a problem, develops a plan, identifies solutions**
2. ***Visualize* data through charts and graphs**
3. ***Assimilate* data from different sources**
4. **Use *Logic* when computing and interpreting probabilities**
5. ***Understand* units of measurement and scale, recognize sampling bias**
6. ***Analyze* data using different quantitative methods and draw conclusions**
7. ***Translate* quantitative language into verbal assumptions**
8. ***Express* quantitative evidence effectively in oral or written communication**

The QLAT addresses six of the eight student learning outcomes. It does not address exploring (Explore) and expressing (Express) data. Each question is associated with three levels of cognition (Basic, Intermediate or Advanced) as documented by the Webb and Bloom taxonomy levels of cognition mentioned earlier. Three samples are provided here for visualizing and analyzing data, and computing probabilities.

- Visualize: You are in the market to buy a car with the best gas mileage. How can this graph help you determine one quality you might look for in a car?

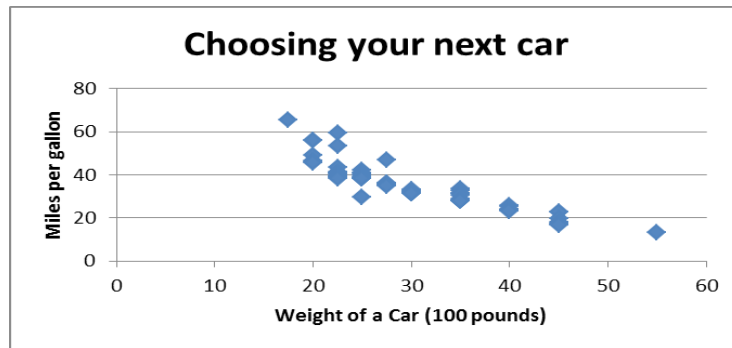


Figure 1: Scatterplot of Miles per gallon versus Car Weight

- Logic: The following table represents the number of males and females (promoted and not promoted) at a local company.

	Promoted	Not Promoted	Total
Males	20	10	30
Females	15	5	20
Total	35	15	50

Out of all employees in the company, what proportion are males?

Out of all employees in the company, what proportion is male and has not been promoted?

- Analyze: The following dataset represents the times, recorded in seconds, for two Olympic competitors at three separate track meets.

100 Meter Dash Times for two Olympic competitors

Runner 1	9.75	10	10.25
Runner 2	9.5	10.5	11.5

Who has the slower average running speed?

Which runner would you send to the Olympics based on consistent performance?

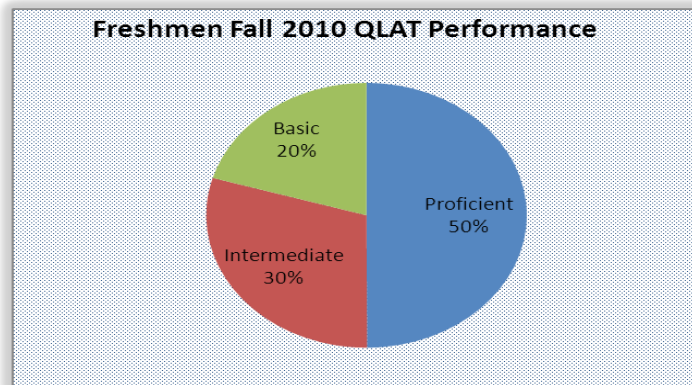
The QLAT assesses, at most, a basic and intermediate level of cognition. Advanced levels of cognition are not possible on the QLAT, as students are not asked to create or develop a project. Some items are designed to increase with difficulty. The QLAT is a collection of questions which address information students should know and have covered at the secondary school level.

3. Results

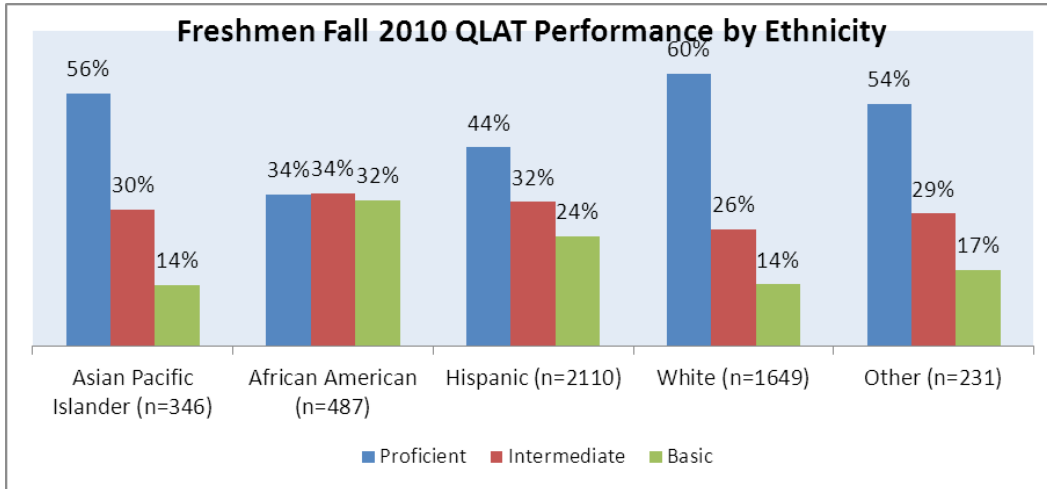
2.1 Another Secondary Subhead

The QLAT is a measure of a student's quantitative literacy (QL) level. Each summer the department of testing services administers the Quantitative Literacy Assessment Test (QLAT) to all incoming freshmen as a part of their student orientation process. The results presented below are a summary of the freshmen performance from the fall of 2010.

There are 20 questions on the QLAT and students are given up to 30 minutes to complete the exam. Based on their score, students are classified as having one of three different levels of literacy. Students are said to be *proficient* for getting 16 or more questions correct, *intermediate*, for getting 12 to 15 questions correct and *basic* for getting less than 12 questions correct. Thirty-six percent of the 2010 freshmen group scored at the intermediate level, and fourteen percent scored at the basic level. This is troublesome given UTSA's predominately minority population-more than fifty percent.



Overall, 34% of African American students and 44% of Hispanic students scored at the proficient level as compared to 60% Whites.



The QLAT was also compared to the student’s performance on the math portion of the Scholastic Aptitude Test (SAT). The results show a positive correlation ($\rho = 0.576$) between Math SAT and the QLAT scores, which confirms that our instrument does assess and provide added information for measuring student’s quantitative literacy.



Further analysis indicates a disparity between male and female performance. This gender disparity is not reported at the national level and future analysis will be performed to investigate the differences.

Principal Component and Factor analyses were run on the test data. Composite scores were created based on the specific learning outcomes tested [Visualize, Logic, Analyze and Other]. The factor analysis showed one dominant factor, indicating a measure of “overall quantitative ability”. A second factor contrasted performance on the Visualize dimension (graphs, charts) to performance on the other three outcomes. Essentially,

students scored well on questions that required direct calculations and reading numbers from charts. However, students performed poorly on items that required them to compare two sets of data or two graphs. Students also struggled with items that required them to read and critically evaluate statements about data. The instrument provides a baseline for item level data which will allow for longitudinal assessment during the student's program of study.

4. Conclusion

The UTSA Quality Enhancement Plan is integrating quantitative literacy (QL) into the general education. Courses with the quantitative component will be designated as Q-courses. A call for proposals went out to the faculty in October of 2010. A major requirement of each proposal was to demonstrate the need to integrate QL into their specific discipline, show how QL would enhance student education, and have a plan to sustain QL for years to come.

A program committee was created to review the proposals (at least one lead faculty member from each college made up the members of the program committee) to select disciplines for a course redesign. The first cohort of faculty is comprised of eight disciplines:

1. Introduction to Physical Anthropology
2. Introduction to Archaeology
3. Introduction to Astronomy
4. Contemporary Biology I
5. Biosciences I
6. Geology - The Third Planet
7. Introduction to Sociology
8. Economics – Economic Principles and Issues, Introductory Macroeconomics, Introductory Microeconomics

Faculty received a stipend and attended a one week workshop on course redesign. A major focus of the workshop is to seamlessly integrate QL into their course through discipline specific assignments. For example, Anthropology developed an assignment where students would collect data on animal behavior at the local zoo. The next requirement is to use technology, Excel spreadsheets, to analyze the data using numerical and graphical summaries. Students are then asked to write a summary of their findings. This assignment addresses all eight of the student learning outcomes (EVALUATE) and meets the goal to enhance student learning through quantitative literacy.

We also have a process in place to collect item level and student level data. UTSA's QEP allows for the employment of undergraduate and graduate teaching assistants to tutor and help with grading. The faculty are not overburdened with grading projects and assessment is collected based on the eight student learning

outcomes (EVALUATE). Our plan allows for a longitudinal study and will track each student's progress as they complete their degree program.

Our QLAT is a baseline instrument used to assess what freshmen know. UTSA's Quantitative Scholarship plan is to use this information as a starting point for students and a focusing point for teachers. The program's plan is to collect the data through the next five years with a goal of tracking an increase in quantitative literacy.

Research shows students retain information well when it is taught in context and through repetition. Repeated learning is achieved through integrating quantitative reasoning (QR) in multiple courses. UTSA's first cohort integrates QR in the fall of 2011 and has over 20 faculty members now teaching a Q-course. The program ***Quantitative Scholarship: From Literacy to Mastery*** currently impacts more than 60 course sections and over 4000 students.

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