Seaver College, Pepperdine University

Quantitative Reasoning Assessment

February 19, 2020

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Background

The core competency of Quantitative Reasoning (QR) is defined at Pepperdine as follows:[1]

> "Students will be able to apply mathematical concepts to interpret and analyze quantitative data in order to solve a problem or draw a conclusion."

Here, "mathematical concepts" should be interpreted broadly: it includes computational facility and concepts such as ratios, but also the ability to interpret diagrams and make basic statistical inferences, as well as a larger range of skills. According to the AAC&U VALUE rubric for Quantitative Literacy,[2] QR can be measured along six dimensions:

- *Interpretation:* Ability to explain information presented in mathematical forms (e.g., equations, graphs, diagrams, tables, words)
- *Representation:* Ability to convert relevant information into various mathematical forms (e.g., equations, graphs, diagrams, tables, words)
- *Calculation*
- *Application/Analysis:* Ability to make judgments and draw appropriate conclusions based on the quantitative analysis of data, while recognizing the limits of this analysis
- *Assumptions:* Ability to make and evaluate important assumptions in estimation, modeling, and data analysis
- *Communication:* Expressing quantitative evidence in support of the argument or purpose of the work (in terms of what evidence is used and how it is formatted, presented, and contextualized)

While it would certainly be ideal to collect student work across all disciplines that could be comprehensively evaluated in each of these dimensions, for this initial assessment project, a more modest goal was set: we determined to gather data on the quantitative skills of students enrolled in statistics classes (a broadly-required quantitative course) in a single semester.

Timeline

The plan for assessing QR was developed by the mathematics faculty, in coordination with the Office of Institutional Effectiveness (OIE), during the Spring 2018 semester. The plan was announced to the Divisional Deans in Summer 2018. Data were collected during the 2018–2019 academic year. In Spring 2019, a committee was assembled to analyze the results of the data collection. This report is the product of that committee's efforts.

1 See www.pepperdine.edu/oie/assessment/program-learning-outcomes/assessment_plo_core_competencies.htm

2 See https://www.aacu.org/value/rubrics/quantitative-literacy

Method

The Instrument

The Quantitative Literacy and Reasoning Assessment (QLRA) is an assessment instrument that was developed by faculty at several schools, with the support of an NSF grant, and was first administered in 2012.[3] A revised version was administered the following year to twenty schools,[4] and it has been used at a variety of institutions in the years since 2014. The OIE obtained rights to the instrument for purposes of this assessment. The QLRA has 20 multiple-choice questions, with five possible responses for each.

Alignment with VALUE dimensions

To align the assessment with the VALUE rubric, each item on the QLRA was matched with one of the six dimensions listed above. Calculation was most represented, with six items. Interpretation, representation, and application were each matched with four items. Two items address assumptions. Because the QLRA is a timed, multiple-choice assessment tool, it is understandable that communication did not seem to match any of the items (although we did identify one item as potentially relating to communication). For many of the questions, multiple skills could be relevant; in each case, we chose the skill that we felt was most closely aligned with the question content.

Participants

The QLRA was administered to students enrolled in statistics classes at Seaver. These classes are taught by instructors in Business Administration, Communication, Economics, Mathematics, Psychology, and Sociology. (See the section on “Context” for the rationale behind this decision.)

Originally, all administration of the QLRA was planned for the Fall 2018 semester. However, due to the Woolsey Fire and the subsequent closure of the Malibu campus, several planned sessions were cancelled; thereafter, one session was completed in the Spring 2019 semester.

3 Gaze, Eric; Montgomery, Aaron; Kilic-Bahi, Semra; Leoni, Deann; Misener, Linda; and Taylor, Corrine (2014) "Towards Developing a Quantitative Literacy/Reasoning Assessment Instrument," Numeracy: Volume 7: Issue 2, Article 4.

4 Gaze, Eric, “Results from an NSF TUES Quantitative Reasoning Assessment Project.” MAA Session on Assessing Quantitative Reasoning and Literacy, January 15, 2014

Demographics

In total, 180 students completed the QLRA, representing majors in seven of Seaver's eight academic divisions. The divisions with the largest representation were Business Administration, Communication, Natural Science, and Social Science. This is not surprising, because these are the four largest divisions overall, in terms of the number of declared majors; in addition, they are the four divisions that offer statistics classes. (Religion and Philosophy majors comprise less than 1% of total students at Seaver, and so again it is not surprising that none were present among the participants of this study.)

Business Administration (BUS)	51
Communication (COM)	19
Fine Arts (FA)	1
Humanities and Teacher Education (HUTE)	2
International Studies and Languages (ISL)	6
Natural Science (NASC)	38
Religion and Philosophy (REL)	0
Social Science (SOSC)	59
Undeclared	4

The participants represented the classes of 2019–2022, with a majority being juniors and seniors. Most undergraduates at Pepperdine do not take a quantitative course within a year of graduation, however, so the two largest groups were sophomores and juniors.

First-year (freshman)	24
Second-year (sophomore)	58
Third-year (junior)	70
Fourth-year (senior)	28

The percentage of male (43%) vs. female (57%) students among the participants was roughly representative of the ratio in Seaver College overall (40% male, 60% female).

Male	78

Female	102

The representation of domestic students (83%) vs. international students (17%) was also close to the ratio in Seaver College overall (86% domestic, 14% international).

Domestic	149
International	31

Approximately half of the students at Seaver College are white/Caucasian; the same is true among the participants in this assessment whose ethnicity was identified to the college. (The total below is 147, or 82% of the participants.)

White/Caucasian	88
Asian	14
African American	6
Hispanic	28
Two or more races	11

Results

Average across all groups and comparison with other institutions

The average score for all participants was 10.8/20, or **54 %**. This is considerably higher than the average score obtained across all schools that used the QLRA in 2013, which was 46% (approximately 9.1/20). This suggests that Pepperdine students are much better prepared to use quantitative reasoning than most other college and university students. The average score at Seaver is, however, significantly (though not substantially) lower than the average score for selective four-year institutions in 2013, which was 60% (approximately 12/20). Although none of the schools who used the QLRA in 2013 are included in Pepperdine's official list of peer institutions, it is reasonable to assert that the selective four-year institutions from that group represent the closest desirable comparison with previous scores.

Average scores by dimension

In the next table, the scores are broken down by the questions' alignment with the dimensions of the VALUE rubric (see "Background" for a description of each dimension).

VALUE dimension	*Avg score*	*Median*	*Max score*
Interpretation	2.12	2.0	4
Representation	1.86	2.0	4
Calculation	3.82	4.0	6
Application/Analysis	1.77	2.0	4
Assumptions	1.01	1.0	2

Some modest conclusions can be drawn here: student responses seem most accurate on questions whose primary component is computational and least accurate on questions that deal with converting information between different forms of representation. For many, “quantitative reasoning” is synonymous with “calculation,” so this is not a surprising result, but as the VALUE rubric makes clear, quantitative reasoning encompasses a much larger set of skills.

This analysis must be taken guardedly, as the VALUE rubric is primarily intended to assess larger pieces or collections of work, not a single test. Nevertheless, it seems reasonable to adapt its dimensions for purposes of classifying the questions of the QLRA.

Statistical analyses

The following tables and analyses were provided by the OIE.

Statistical differences were observed for sex and international student status, such that males scored higher than females (p <.05), and international students scored higher than domestic students (p <.01; Table 1).

Table 1
Bivariate analysis of average QRLA score

		N	***M***	***SD***	***t***	***df***	***p***
Sex	Male	78	11.68	3.97	2.32	178	0.02
	Female	102	10.17	4.60			
Ethnicity	White	88	10.86	4.68	1.59	145	0.11
	Non-White	59	9.68	4.01			
International status	Domestic	149	10.35	4.43	-3.25	178	0.00
	International	31	13.10	3.45			

In addition, significant differences were observed for division (p <.01). A Tukey post-hoc comparison test revealed significant differences occurred between BUS and COM, COM and NASC, and COM and SOSC.

Table 2

Analysis of variance of average QRLA score

		SS	*df*	*MS*	*F*	*p*
Class level	Between groups	106.12	3	35.37	1.86	0.14
	Within groups	3348.19	176	19.02		
	Total	3454.31	179	19.30		
Division	Between groups	244.16	3	81.39	4.73	0.00
	Within groups	2818.98	164	17.19		
	Total	3063.14	167	18.34		

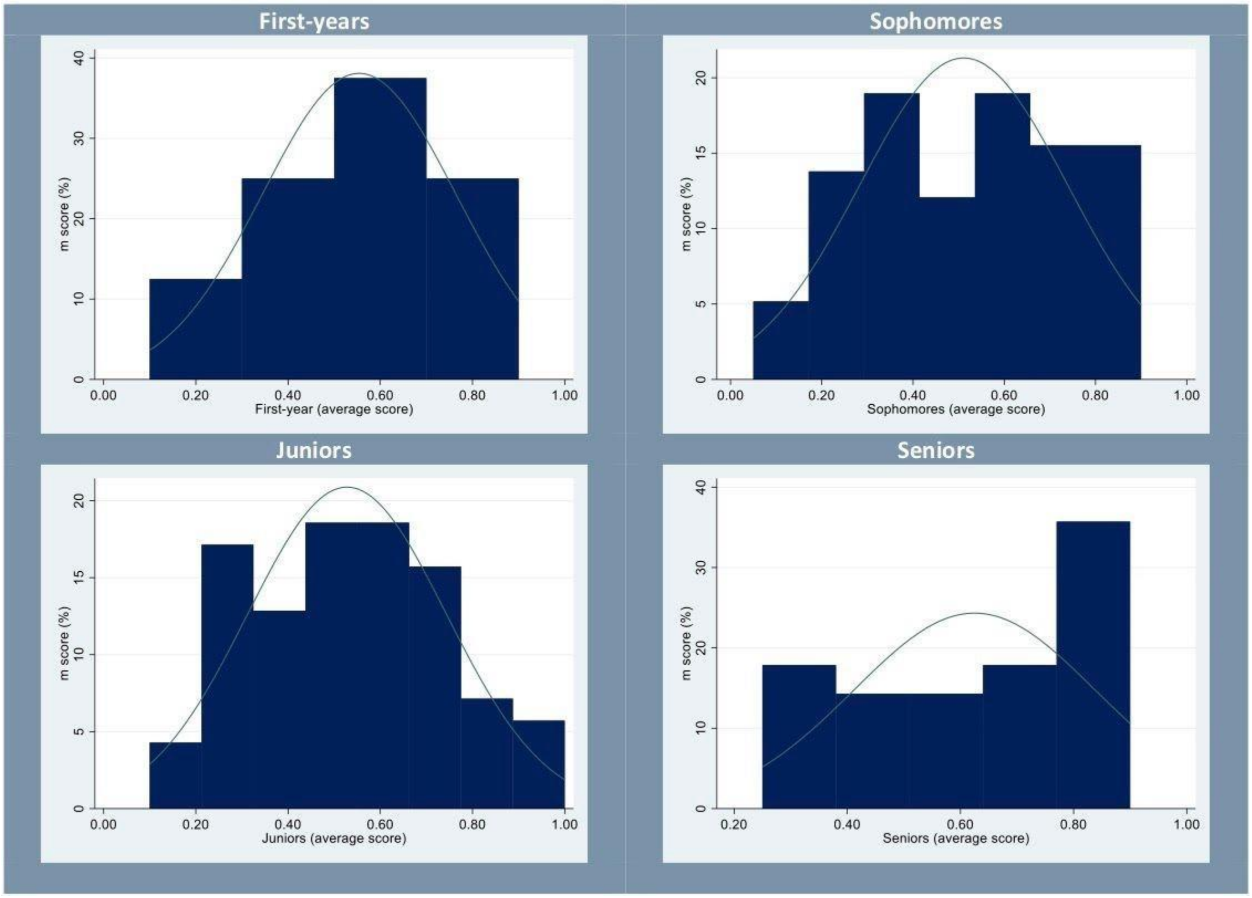
Averages by class year:

First-year (freshman)	11.08	55%
Second-year (sophomore)	10.22	51%
Third-year (junior)	10.56	53%
Fourth-year (senior)	12.50	63%

When first- and second-year students are excluded, the overall average score increases slightly to 56%. This is insufficient evidence to claim that students' quantitative reasoning skills are improved significantly during their time at Pepperdine. We do note, however, that fourth-year students (15.5% of the total participants) scored higher, on average, than the comparison group of selective four-year institutions in 2013

The histograms below show the distribution of scores for each class year.

Figure 1. *Histogram of scores for Class Level*



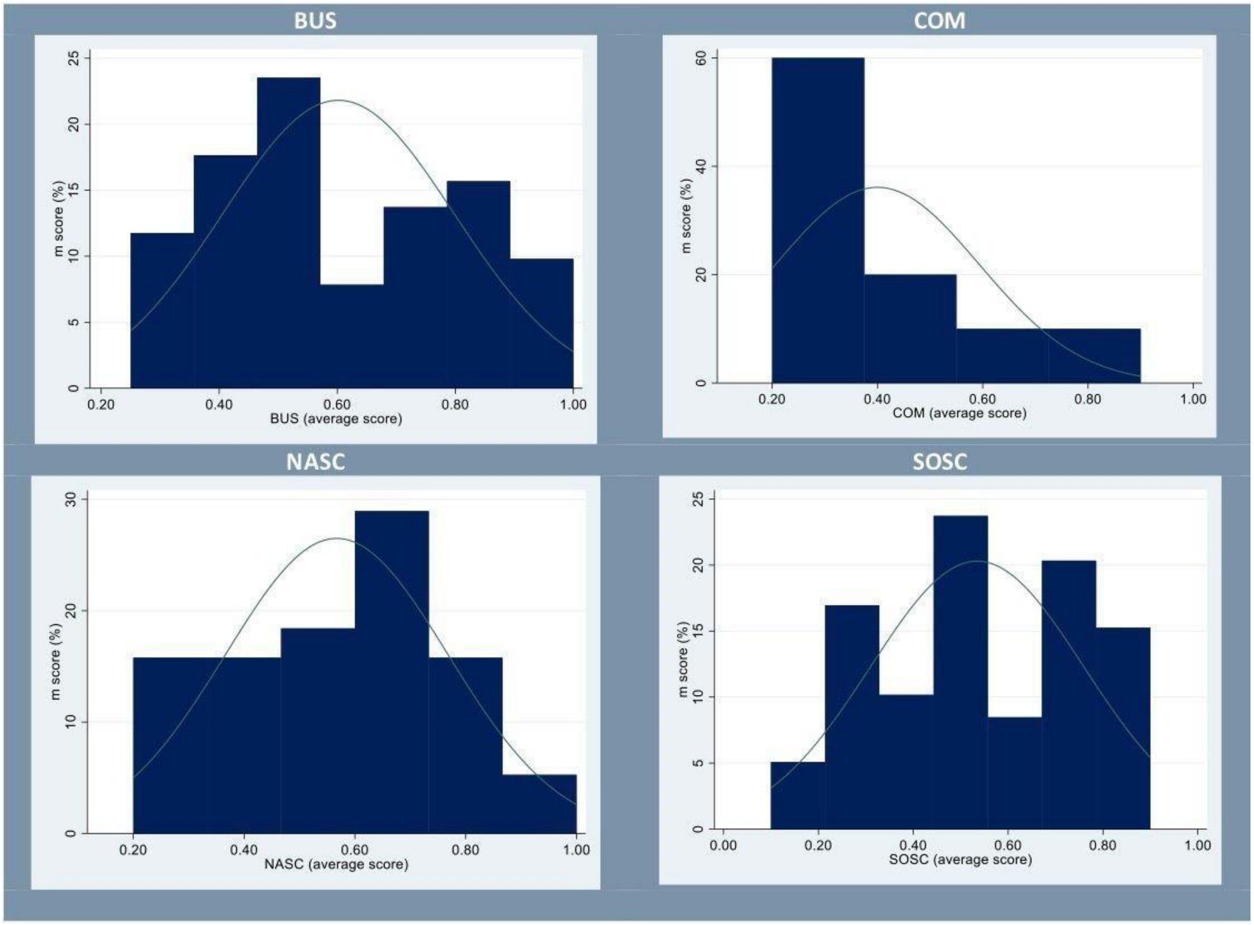
Averages by division:

BUS	12.04	60%
COMM	8.00	40%
NASC	11.34	57%
SOSC	10.69	53%

It is noteworthy that the Business division not only outperformed the other divisions, but also was the only division that scored higher, on average, than the comparison group of selective four-year institutions in 2013.

The histograms below show the distribution of scores for each division.

Figure 2. *Histogram of scores for Division*



Student perceptions of QR

In addition to the 20 quantitative questions of the QLRA, students were asked to complete a short survey about how they perceive the importance of quantitative literacy as well as their own ability in this core area. The first five elements of the survey were the same as those included on the 2013 QLRA; the sixth was added for this assessment.

Not every student responded to every survey element, so the number # of responses is included for each question.

Statement	#	*SA*	*A*	*N*	*D*	*SD*
Numerical information is useful in everyday life.	177	52%	39%	8%	1%	0%
Numbers are not necessary for most situations.	177	1%	12%	25%	47%	14%
Quantitative information is vital for accurate decisions.	177	37%	44%	16%	3%	0%

Understanding numbers is as important in daily life as reading and writing.	177	41%	39%	12%	6%	2%
It is a waste of time to learn information containing a lot of numbers.	175	2%	3%	13%	43%	38%

These results show that Pepperdine students generally value quantitative skills; in responding to each of the statements above, between 60–90% of students answered in a way that indicates agreement that QR is important. (Notice that the second and fifth statements are phrased so that "disagree" indicates a positive opinion of QR.)

However, only about half are more than somewhat confident in their ability to use QR. In response to the question "How confident are you in your ability to use quantitative reasoning?";students provided the following answers. (Total number of responses: 176)

Completely confident	Very confident	Somewhat confident	Slightly confident	Not at all confident
16%	35%	38%	9%	3%

Discussion

Context

Quantitative Reasoning is in a difficult position, both within the larger cultural setting and within the Seaver curriculum. Despite a widespread increased emphasis on fields in STEM (science, technology, engineering, and mathematics), quantitative skills—whether in formal mathematics or more generally in issues of "numeracy"—remain a source of discomfort for many people. In the 1987 book *Cultural Literacy: What Every American Needs To Know*, E. D. Hirsch wrote, while discussing scientific knowledge generally:

> "The gap between the essential basic knowledge of science and what the general reader can be expected to know has become too large." [5]

This observation may be applied particularly to quantitative literacy, in an age where massive amounts of data are available and numerical analysis can shape both perception and understanding. Yet even within academia, many faculty, whose specialties often lie outside of the natural or social sciences, seem to shy away from issues that are perceived to demand mathematical reasoning.

[5] E.D. Hirsch, Jr, Kett, Joseph F., Trefil, James, (2012), The New Dictionary of Cultural Literacy, Houghton Mifflin Company, NY.

Currently, the General Education (GE) program, which includes 63–64 units of course credits, has only 7 credits that are related to developing QR: 3 in mathematics, and 4 in laboratory science. This situation was taken into serious consideration during the development of this assessment plan for QR at Pepperdine. The setting of statistics classes for administration of the QLRA was chosen in order to avoid the threat of math anxiety that could be posed by an exam given outside of any quantitative context.

At a school with a reputation as strong as Pepperdine's (tied for #20 nationally among the best for undergraduate teaching in the 2019 U.S. News and World Report rankings), it is striking to see a sample of students scoring on average 55%, even on a multiple-choice test. It is hardly less striking that the comparison group of selective four-year institutions in 2013 scored only 60% on average. It seems desirable to improve quantitative skills in the population generally; this is a potential area in which Pepperdine could become a leader.

Faculty response and next steps

Several faculty conversations have been held since the administration of the QLRA.

Within the Business Administration Division, faculty described necessary quantitative reasoning skills as reading numeric data, making appropriate calculations with data, communicating the results, and drawing valid conclusions. They place high expectations on their own students and agree that quantitative skills are essential for all Pepperdine students.

The Communication Division examined the support that their curriculum provides for students to practice quantitative reasoning. The faculty determined that their students should have additional training in quantitative skills, especially prior to reaching the capstone level, as capstone projects typically require the use of statistical analysis. They committed to advising students to take statistics early in their studies, and to provide scaffolding in upper-level classes that will further equip students with the needed skills.

In the Natural Science Division, faculty recognized that, while quantitative skills are certainly essential, students may try to avoid those parts of labs or projects that demand quantitative reasoning. The perception is that the math and science GE requirements have historically been given primary responsibility for developing quantitative skills in the general Seaver population, and that these requirements are insufficient to reach the goal of mastery. The faculty would like to see broader development of quantitative skills in the Seaver curriculum, either through the individual majors or the GE program.

The Social Science Division did not have a representative on the assessment committee, but its faculty should certainly be included in future discussions about the role of quantitative reasoning in the Seaver curriculum.

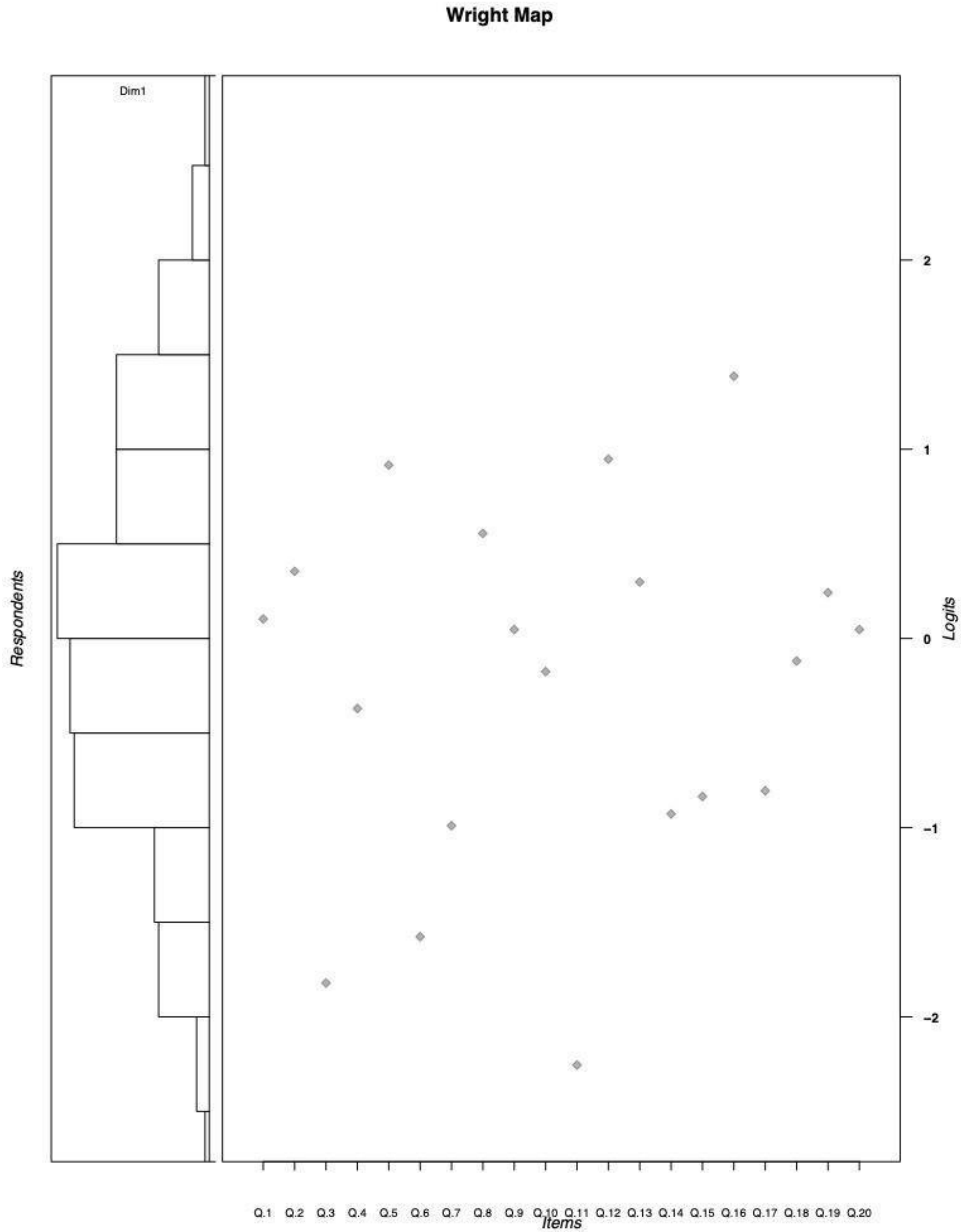
The college is currently in a period of re-evaluating the GE program. In discussions hosted by members of the GE committee, there has been general agreement that quantitative reasoning should be emphasized as one of the primary components. Indeed, most stakeholders have mentioned scientific and quantitative literacy as core outcomes of the curriculum. Faculty have thereby expressed a renewed commitment to developing quantitative skills as part of the GE curriculum.

Based on the results of the survey of student attitudes, the college should also work on improving student confidence in using quantitative reasoning, as students generally agree that quantitative reasoning is important but do not seem very confident in their abilities.

Appendix: Wright Map analysis of the QLRA

An analysis of Pepperdine student performance on the QLRA, using a Wright Map, shows that it does a good job of discriminating between student ability. The Wright Map is shown on the next page.

In general, Wright Maps are used to determine the probability of people at a specific ability level (the histogram on the y-axis in the figure below) will answer a test item (the scattered points) correctly. An item and person at the same level (i.e. -1 logits, or item 7 and the 8th category of respondents) means that the people at that level have a 50% probability of answering the question correctly. This figure also shows the easiest items (nearest the bottom), and most difficult items (nearest the top). Items that are too easy may still provide meaningful information, but items that are too difficult might be due to other issues (i.e. language, context, etc.) other than the mathematics skill.


Wright Map
Dim1
Respondents
Logits
2
1
0
−1
−2
Q.1 Q.2 Q.3 Q.4 Q.5 Q.6 Q.7 Q.8 Q.9 Q.10 Q.11 Q.12 Q.13 Q.14 Q.15 Q.16 Q.17 Q.18 Q.19 Q.20
Items