Understanding Students' Quantitative Reasoning Skills:

Summary of Evidence from Spring 2020

Cal Poly Pomona (CPP) is deeply committed to ensuring an educational experience that fosters student learning and success for every student. As part of that commitment, the Office of Assessment and Program Review leads the assessment of undergraduate learning outcomes each year, focusing on gathering evidence of *Quantitative Reasoning* in 2019-2020. The evidence is used to understand student learning and experiences concerning their quantitative reasoning skills. The findings also assist the institution in learning about potential equity gaps, and subsequently identifying additional resources to improve the undergraduate experience in quantitative reasoning.

Quantitative Reasoning is both an institutional[1] and a General Education (GE)[2] learning outcome at CPP, as well as a WSCUC Core Competency[3]. The GE learning outcome is defined as being able to apply and communicate quantitative arguments using equations and graphical representations of data, while the institutional learning outcome on integrative thinking considers the ability to apply mathematical concepts to the interpretation and analysis of qualitative information in order to solve a wide range of problems.

This report summarizes the findings of student achievement regarding *Quantitative Reasoning* from a combination of direct evidence via a CPP faculty-developed quiz, and indirect evidence drawn from student responses to related questions on the 2020 National Survey of Student Engagement (NSSE[4]).

Direct Evidence: Quantitative Reasoning Rubric

Methodology

In Fall 2019, a task force consisting of faculty from multiple disciplines developed a quiz to assess various criteria outlined in the rubric used to assess quantitative reasoning (Appendix A). In Spring 2020, all 12,327 students with senior standing were invited to participate in this quiz via Blackboard. Faculty teaching B5 synthesis courses were also urged to encourage their students to participate. The quiz included seven multiple choice questions, one fill-in-the-blank question, and two open-ended questions. Questions were designed to align with the elements of the Quantitative Reasoning Rubric (Appendix A). The quiz is available from this web link.

A total of 1,081 seniors completed the quiz, reflecting a response rate of nine percent. A random sample of 489 seniors representing the eight colleges and reflecting CPP's undergraduate population was selected for scoring. Prior to scoring, identifying information (e.g., names) was redacted from the quizzes in the sample to minimize scoring bias.

The multiple choice and fill-in-the-blank items were scored automatically by Blackboard. The open-ended items were scored by a group of nine faculty from multiple colleges using rubrics (Appendices B and C). These faculty participated in a norming session in Summer 2020 to calibrate the Rubrics and their application to sample artifacts for the open-ended questions. Thereafter, over a two-week period, each artifact consisting of the same two open-ended questions was read and scored independently by two faculty members. Artifacts with discrepancies greater than two points in scores were scored by a third reviewer. Subsequently, averages for each Rubric criterion were calculated for every student using the Blackboard- and faculty-scored questions, and then rounded to the nearest whole number.

The Rubric[5] defined quantitative reasoning through four criteria (data representation, calculation, application/analysis, and communication) and three levels of performance (introductory, developing, and mastery.)

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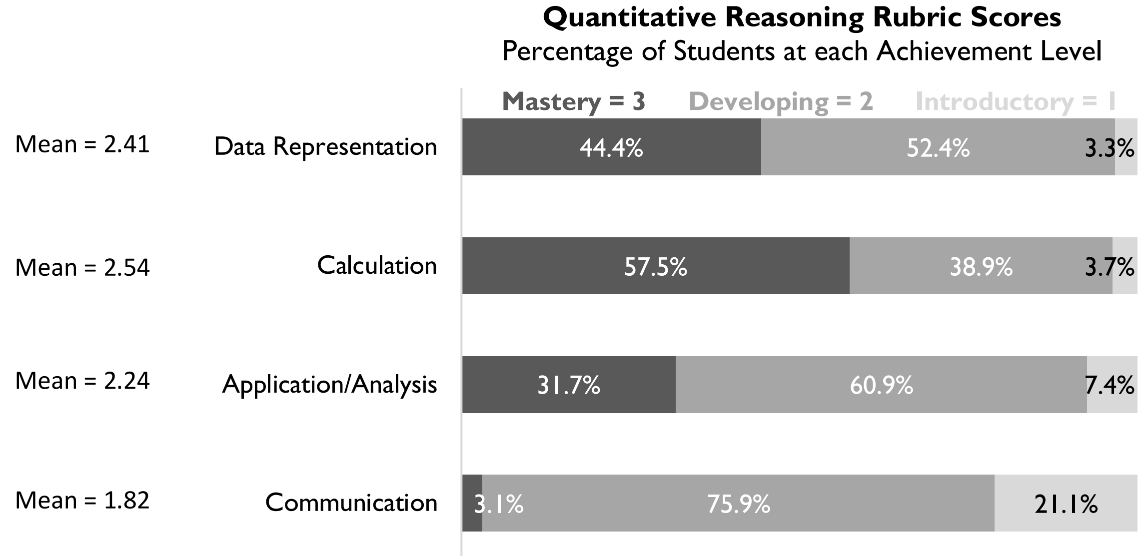
[1] https://www.cpp.edu/~assessment/learning-outcomes/institutional-learning-outcomes.shtml
[2] https://www.cpp.edu/~assessment/learning-outcomes/ge-student-learning-outcomes.shtml
[3] https://www.cpp.edu/~assessment/learning-outcomes/core-competencies.shtml
[4] https://nsse.indiana.edu/
[5] Approved by the Academic Programs Assessment Committee (APAC) and GE Assessment Committee (GEAC.) See Appendix A.

Results

The chart below displays the overall percentage of students who scored at each level of achievement in each criterion.



The results show uneven distribution of student performance in each criteria of quantitative reasoning. CPP students performed strongest in *calculation.* While 57.5%% of our seniors performed at the "mastery" level for *calculation*, 38.9% were at the "developing" stage and 3.7% performed at the "introductory" level.

In terms of *data representation,* 44.4% of CPP seniors demonstrated the "mastery" level, while 52.4% were at the "developing" level and 3.3% were at the "introductory" level. In other words, more than half (55.7%) had not achieved "mastery" where we expect students to convert relevant information into an appropriate and desired portrayal of data. *Application/analysis* is concerned with judging and drawing appropriate conclusions based on the quantitative analysis of data. Here, only 31.7% of CPP seniors performed at the "mastery" level, while 60.9% demonstrated a "developing" level of performance, and 7.4% performed at the "introductory" level.

Communication is at the top of Bloom's Taxonomy of thinking order skills where students are expected to express quantitative evidence in support of an argument or purpose of the work. Essentially, we are concerned with the extent to which students were able to use, present, and contextualize data where only 3.1% of CPP seniors performed at the "mastery" level, while 75.9% were still in the "developing" stage, and 21.1% were at the "introductory" level.

Additional analyses were conducted to compare student performance by groups where equity gaps are typically reflected; that is, enrollment in STEM majors, under-represented minority (URM) status, and sex. Statistically significant differences were found for all four quantitative reasoning criteria. In other words, STEM majors demonstrated stronger levels of quantitative reasoning than non-STEM majors, non-URM students performed better than URM students, and males performed better than females in all four criteria. Further, statistical analyses revealed that males scored higher than females regardless of whether they were enrolled in a STEM or non-STEM major.

Quantitative Reasoning by Gender

The first chart in Appendix D displays the percentage of males and females at each level of performance in each criterion. As evident, a greater percentage of males performed at the mastery level in comparison to females across all criteria. The greatest difference between male and female performance was in *calculation* with a difference of 15% at the mastery level.

Quantitative Reasoning by URM Status
The second chart in Appendix D displays the percentage of non-URM students and URM students at each level of performance in each criterion. Data show that a greater percentage of non-URM students performing at the mastery level in comparison to URM students. The greatest disparity between non-URM and URM students was seen in *calculation* with a difference of 16% at the mastery level.

Quantitative Reasoning by STEM Status
The final chart in Appendix D displays the percentage of STEM and non-STEM major students at each level of performance in each criterion. Students enrolled in STEM majors performed at higher levels than non-STEM majors on all criteria. Here, we see a difference of 20.1% between STEM and non-STEM majors in *application/analysis* mastery. It is also notable that 16.6% more STEM major students scored at the mastery level for *calculation* than non-STEM major students.

Indirect Evidence: National Survey of Student Engagement (NSSE)

Methodology
As part of CPP's commitment to ensuring educational experiences that foster student learning and success, CPP participated in the National Survey of Student Engagement (NSSE) in Spring 2020. With a response rate of 25%, this survey collected information from 1,747 first- and senior-year students regarding their participation in various educational practices.

NSSE scores serve as complementary indirect evidence of student learning concerning quantitative reasoning. In addition, as the test is national, benchmark data from comparative institutions is provided from this web link.

Results
CPP seniors reported that they "sometimes" engage in quantitative reasoning tasks and did so with greater frequency than CPP first-year students, and significantly more often than their peers at comparator institutions. Furthermore, seniors reported that CPP contributed "quite a bit" to their knowledge and skills regarding analyzing numerical and statistical information, which is significantly more than their peers at comparator institutions. The tables below detail mean responses to quantitative reasoning-related questions disaggregated by first- and senior-year students and by comparison groups.

During the current school year, about how often have you done the following:					
1 = Never, 2 = Sometimes, 3 = Often, 4 = Very often		**Mean Response**			
		CPP	**Master's**	**CSU**	**NSSE TOTAL**
Reached conclusions based on your own analysis of numerical information (numbers, graphs, statistics, etc.)?	FY	2.6	2.6	2.5	2.6
	SR	2.8	2.6*	2.6*	2.7*
Used numerical information to examine a real-world problem or issue (unemployment, climate change, public health, etc.)?	FY	2.4	2.4	2.3	2.3
	SR	2.5	2.5	2.4*	2.4*
Evaluated what others have concluded from numerical information?	FY	2.4	2.3	2.3	2.3
	SR	2.6	2.4*	2.4*	2.4*

**Please note that these scores are significantly different from the corresponding CPP score, p < .05*

How much has your experience at this institution:					
1 = Very little, 2 = Some, 3 = Quite a bit, 4 = Very much		**Mean Response**			
		CPP	**Master's**	**CSU**	**NSSE TOTAL**
Contributed to your knowledge, skills, and personal development in analyzing numerical and statistical information?	FY	2.8	2.7*	2.7*	2.7*
	SR	3.1	2.9*	2.9*	2.9*

**Please note that these scores are significantly different from the corresponding CPP score, p < .05*

Summary

The evidence from our internal assessment coupled with the NSSE findings reveal uneven levels of quantitative reasoning skills on the part of CPP seniors. These skills are crucial for all students as comfort with using quantitative reasoning skills is necessary for many aspects of 21st century living, including the consumption, evaluation, and decision-making associated with budgets, political polls, or even converting a recipe.

While it is encouraging that nearly 58% of seniors demonstrated a "mastery" of calculation skills, it is, nonetheless, concerning that only about 3% performed at the "mastery" level for *communication*. This means that 97% of our graduating seniors did not demonstrate the expected ability to effectively communicate quantitative data. In addition, only about 44% of seniors demonstrated "mastery" of data representation (the ability to convert quantitative information to other forms, like graphs or words), and only about 32% demonstrated "mastery" of application/analysis (the ability to draw conclusions based on the quantitative analysis of data).

Of great concern is that we found equity gaps in student performance. Males performed better on quantitative reasoning tasks than females, non-URM students performed better than URM students, and STEM majors demonstrated stronger levels of quantitative reasoning than non-STEM majors. The differences between STEM and non-STEM majors might be attributed to the curriculum focus on quantitative reasoning content for STEM majors, whereas non-STEM majors may not be exposed to quantitative reasoning tasks as frequently (Rocconi, Lambert, McCormick, & Sarraf, 2013). However, further examination of the scores revealed that males scored higher than females regardless of major type. These findings prompt further questions concerning the extent to which bias, conscious or implicit, plays a role in instructional delivery, or stereotype threat impacts women's math performance (Spencer, Steele, & Quinn, 1999), thereby impacting quantitative reasoning skills.

On the NSSE, CPP seniors reported that the institution contributed "quite a bit" to their knowledge, skills, and personal development in analyzing numerical and statistical information. In spite of this, CPP seniors also reported limited experience using numerical information to examine real-world problems compared to other quantitative reasoning experiences in the survey, an important component of quantitative reasoning according to the Association of American Colleges and Universities (AAC&U, 2009). In fact, Elrod (2014), former Interim Provost at CSU, Chico, recommends that higher education seriously consider requiring quantitative reasoning as integrated across the undergraduate curriculum.

While concerning that large percentages of CPP students have yet to reach the "mastery" level in the various criteria in the Rubric, more nuanced data would be helpful in unpacking its implications. For instance, the Rubric consolidated *application/analysis* into a single criterion; separating them into distinct criteria would provide more accuracy. Furthermore, subtleties were lost with the odd-numbered scale used in the Rubric; a four-point scale would parcel out the expanse of the "developing" stage to be more meaningful (i.e., separating the "developing" stage into "developing" and "proficient.") Further discussion with faculty leaders, and approval to adopt an improved and purposeful Rubric is warranted.

As we consider these results in light of the elements of an *inclusive polytechnic university*, it behooves us to question the extent to which we incorporate quantitative reasoning skills in furthering this identity. For instance, what role does quantitative reasoning play in advancing *creativity, discovery and innovation, collaborative thinking, and professional and career readiness?* To what extent do we appropriate quantitative reasoning skills solely to our Math Department, and how do individual degree programs advance critical quantitative reasoning skills in upper-division program courses?

Improving Student Learning

Discussing this report with faculty and/or key staff (e.g., academic advisors, career advisors, etc.) in your program may help determine program-level actions needed to improve student achievement in the Quantitative Reasoning learning outcome. If your program has evidence of learning for a related outcome, it may be useful to consider both assessment outcomes and results as part of your discussion.

The following questions may be useful in guiding discussions:

- For which components/criteria of Quantitative Reasoning do students demonstrated satisfactory levels of achievement? How do students in your program compare?
- For which components/criteria of Quantitative Reasoning do you feel students need to improve?
- What types of assignments are used in your program to develop student's ability to apply and communicate quantitative arguments to solve a wide range of problems?
- To what extent is scaffolded feedback on assignments provided? When/where is it needed the most to strengthen student learning in this outcome?
- What are some course or programs modifications that may facilitate student learning in the necessary quantitative reasoning skills and improve on the components/criteria you identified as needing improvement? While not an exhaustive list, typical categories of changes made as a result of assessment evidence may include:
    - Curriculum (e.g., adequacy of courses, course sequencing, etc.)
    - Pedagogy (e.g., more quantitative reasoning assignments, provide scaffolded assignments or prompts to ensure students acquire the skills, dedicate a specific amount of class time to a skill identified as needing improvement, incorporate a class activity to enhance student learning, etc.)
    - Resource allocation (e.g., establish a standard syllabus across different sections for a key course, develop a departmental peer tutoring program, etc.)
- What recommendations do you have for CPP to improve students' quantitative reasoning skills?

We recommend keeping a record of the decisions your program makes about the evidence, and the actions taken to improve Quantitative Reasoning skills. This information may be useful when completing future assessment reports and program review/accreditation self-studies.

References

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