State Council for Higher Education for Virginia
Assessment of Competencies
Quantitative Reasoning
UNIVERSITY OF MARY WASHINGTON
2021

GENERAL EDUCATION AT THE UNIVERSITY OF MARY WASHINGTON

General Education is the foundation of a liberal arts education and is designed to cultivate the skills, knowledge, values, and habits of mind that are essential in every field of study and which enable graduates to make effective decisions as citizens of a rapidly changing, richly diverse, and increasingly interconnected world. The University's General Education requirements introduce students to a variety of learning perspectives and methods of inquiry, which combine to foster an appreciation of the connections between different ways of viewing, knowing, and engaging with the world. In particular, the General Education curriculum should:

- develop core skills that enable students to understand, evaluate, articulate, and advance their ideas and the ideas of others. Across their General Education courses, students learn to think critically, analyze data, evaluate evidence and the arguments and theories grounded in that evidence, conduct research thoroughly and with integrity, write and speak effectively, and be in command of the technologies that define not only 21st-century communication but also the emerging tools of different disciplines.

- challenge students to explore issues, solve problems, and learn though multiple methodological approaches. General Education offers a wide-range of courses challenging students to make connections across their course of study and to explore the variety of ways they can understand and apply what they learn. They achieve this through studying complex problems and issues in the arts, humanities, quantitative reasoning, and natural and social sciences.

- prepare students to engage knowledgably and responsibly with a changing, complicated, and multi-dimensional world. University of Mary Washington students must understand and appreciate global connections, differences, cultures, languages, environments, and change. These courses require students to be both individual and collaborative learners, solve problems systematically and creatively, and find opportunities to explore beyond the classroom experiences such as undergraduate research, internships, study abroad, and engagement in community and civic life.

These goals were the basis for the development of the new General Education curriculum, where requirements were placed into three overarching categories: Foundations, Methods of Investigation, and Connections. Courses in the Foundations category will establish skills for later success at UMW, are fundamental to the liberal arts, and ideally should be taken early in the academic career. Methods of Investigation consist of lower level courses that explore how different disciplines approach critical thinking, research, and problem-solving. Connections courses will build on prior requirements to help students make links between classroom knowledge, the world, and their life beyond UMW. This arrangement of the courses emphasizes the skills and knowledge that will be gained from each required course and clarifies the benefits that will be acquired through the completion of the General Education curriculum through this framework.

The General Education curriculum and the Honor System are both integral parts of the educational experience at UMW. It is expected that students will devote their authentic selves to each course, will learn and respect relevant disciplinary norms, and will conduct themselves with integrity in

accordance with the honor pledge made upon arriving at Mary Washington in the completion of this curriculum.

CORE COMPETENCIES IN THE STATE OF VIRGINIA

In 2017, the State Council of Higher Education for Virginia established a policy on Student learning Assessment and Quality in Undergraduate Education. Goal #2 of the *Virginia Plan for Higher Education* directs SCHEV to "optimize student success for work and life," and, specifically, to "strengthen curricular options to ensure that graduates are prepared with the competencies necessary for employment and civic engagement." Priority Initiative #4 for 2016 includes a commitment to "collaborate with institutions to measure the quality of undergraduate education, including civic engagement of graduates and relevance to demand occupations across regions of the state." The 2017 policy identifies four core competencies for student success to be assessed by all institutions:

1) **Critical thinking** – the ability to subject one's own and others' ideas, arguments, assumptions, and evidence to careful and logical scrutiny in order to make an informed judgment, draw a sound conclusion, or solve a problem.

2) **Written communication** – the ability to develop and communicate ideas effectively in writing as appropriate to a given context, purpose, and audience. It includes a variety of styles, genres, and media, including computer-mediated communications.

3) **Quantitative reasoning** – the ability to manipulate, analyze, and/or evaluate numbers and numerical data. It may involve calculation and/or analysis and interpretation of quantitative information derived from existing databases or systematic observations, and may be based in a variety of disciplines, not limited to mathematics and the natural and physical sciences.

4) **Civic engagement** – an array of knowledge, abilities, values, attitudes, and behaviors that in combination allow individuals to contribute to the civic life of their communities. It may include, among other things, exploration of one's role and responsibilities in society; knowledge of and ability to engage with political systems and processes; and/or course-based or extra-curricular efforts to identify and address issues of public or community concern.

Two additional core competencies are selected by the institutions themselves. At the University of Mary Washington, these competencies are:

5) **Oral communication** – The ability to communicate effective oral messages in a variety of settings, including public speaking, group discussion, and interpersonal communication; the ability to plan, organize, support, and deliver ideas and arguments, and utilize a variety of research techniques to synthesize information and support their messages.

6) **Digital Fluency** – Digital fluency is the ability to consume and produce digital knowledge critically, ethically, and responsibly, as well as to creatively adapt to emerging technology.

The calendar for UMW's reporting of these core competencies is below:

SCHEV Competencies Review Calendar							
2018-2019	**2019-2020**	**2020-2021**	**2021-2022**	**2022-2023**	**2023-2024**	**2024-2025**	**2025-2026**
	Civic Engagement (early)			Civic Engagement			Civic Engagement
Critical Thinking (early)				Critical Thinking			Critical Thinking
		Digital Fluency			Digital Fluency		
Oral Communication			Oral Communication			Oral Communication	
		Quantitative Reasoning (late)			Quantitative Reasoning		
Written Communication			Written Communication			Written Communication	

Quantitative Reasoning at UMW

Quantitative literacy is essential to be an informed citizen and productive in the workplace. Equipping graduates with quantitative reasoning skills prepares them to meet their future responsibilities. UMW recognizes that college graduates will live in a world where many decisions will be made based on quantitative data and reasoning. Decision making such as assessing risk when buying insurance, interpreting poll results for upcoming elections, evaluating success rates for medical procedures, understanding mathematical models, and predicting the stock market are examples of situations that college graduates will face as they integrate into society. Therefore, equipping college graduates with quantitative reasoning skill sets that facilitate personal and professional development remains one of the cores of the liberal arts education at the University of Mary Washington.

At Mary Washington, students are taught how to make informed judgments using quantitative information through a course with a quantitative reasoning (QR) designation. QR courses teach students to identify reliable data, to weigh evidence and understand probabilities, to think critically to solve complex problems in a variety of contexts, to make connections to other disciplines, and to interpret and communicate their results while recognizing and avoiding the fallacies and pitfalls which frequently surround the use of quantitative information.

The following learning outcomes are used both for assessing UMW's General Education requirement in Quantitative Reasoning and the SCHEV core competency of Quantitative Reasoning. These four criteria are expressed in material, assignments and exams for all courses offered at University of Mary Washington that fulfill the QR requirement.

Learning Outcomes:

- Students will demonstrate the ability to produce and interpret quantitative information in various forms such as graphs, equations, diagrams, etc.
- Students will use appropriate methodologies to draw valid conclusions based on quantitative information.
- Students will be able to discern the validity and accuracy of an argument or conclusion derived from available numerical information.
- Students will apply quantitative techniques to address multiple issues of contemporary significance in technology or society.

Standard(s) for Proficiency:

There are five rating categories (i.e., *limited, average, good, high and 0 for not demonstrated*) for each SLO. Seventy-five percent of students must pass each SLO with a rating of 2 (average) or higher. The evaluation categories are the same as those used in university assessments of QR.

Description of Methodology Used to Gather Evidence of Proficiency:

In consultation with the academic departments offering the QR designated courses, the Office of Institutional Analysis and Effectiveness selects a sample of courses for assessment during the fall and spring semesters. OIAE reaches out to the faculty teaching that course and works with them to determine appropriate artifacts for assessment. Considering the diverse nature of the courses fulfilling this requirement, each academic department has developed a distinct assessment protocol for measuring each of the QR Student Learning Outcomes. The approved protocols allowed for flexibility in the assessment activities and methods that could be used, including multiple choice questions, assignments/projects, practicum, or any other assessment technique that best addressed the unique courses in each academic program (see Appendix 1 for sample questions). The protocols used by each academic program are archived each year and can requested from our office of Institutional Analysis and Effectiveness. In courses larger than thirty, random samples of student work are allowed. Instructors forward their scores for each learning outcome for each student to OIAE for compilation. In 2021, these courses were assessed:

Computer Science 284: Applied Discrete Mathematics
Math 110: Fine Mathematics with Applications
Philosophy 151: Introductory Logic
Statistics 180: Introduction to Statistics

Quantitative Reasoning Benchmark:

For each SLO, the benchmark is that at least 75% of students would achieve a passing score (2 or higher on a 5-point scale from 0-4).

Results:

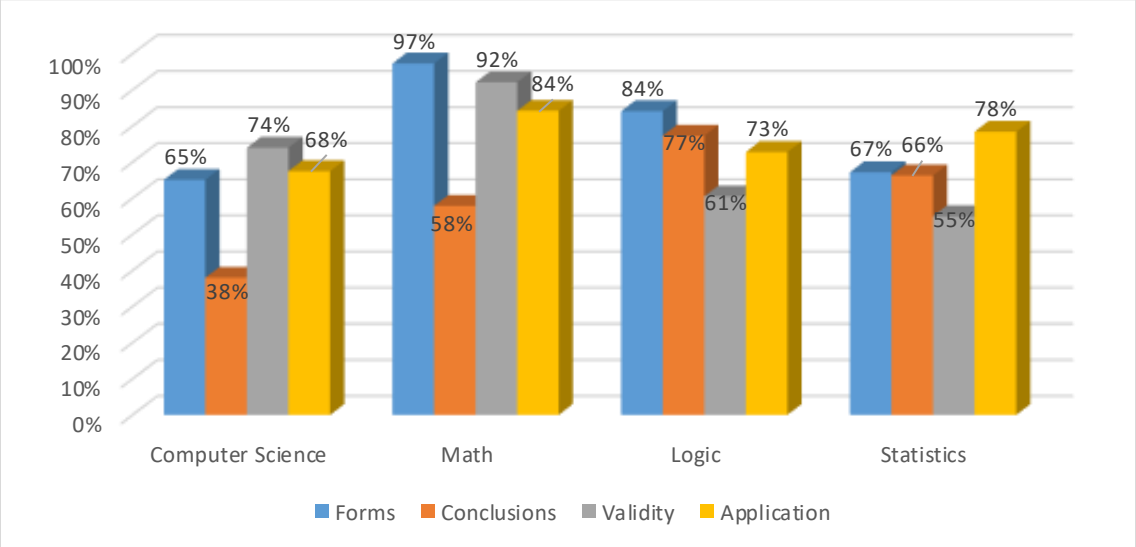
Overall, we did not achieve a 75% passing score for all four of the learning outcomes (see table 1). Student Learning Outcome 1: Forms and Student Learning Outcome 4: Applications were each well above the benchmark, but Student Learning Outcome 2 (Conclusions) and Student Learning Outcomes 3 (Validity) fell below the benchmark, with the score for Conclusions significantly below 75% and the lowest score (only 60% of the students achieved a passing score).

Table 1: Results of Quantitative Reasoning Learning Outcomes

	SLO1: Forms	SLO 2: Conclusions	SLO 3: Validity	SLO 4: Applications
Students evaluated	330	330	330	330
# Passing	298	231	256	292
% Passing	90%	60%	72%	85%

Furthermore, the results vary by the type of Quantitative Reasoning discipline that was assessed, with Computer Science scores more likely to fall below the benchmark (Figure 1). In fact, none of the computer sciences learning outcome scores achieved benchmark status. Some disciplines were stronger in terms of meeting the weaker benchmarks for SLO 2 (Conclusions) than SLO 3 (Validity) than others. It may be that differences across disciplines are associated with different assignments or different scoring practices and rubrics. For example, Computer Science may assess more rigorously for each category. Further discussion may help determine this.

Figure 1: Student Learning Outcomes for QR by Discipline



Summary and Suggestions:

In summary, there are both strong and less strong elements to Quantitative Reasoning at UMW. Student achieved the highest levels of passing scores in Forms and Applications. However, Student Learning Outcome 2, Conclusions ("Students will use appropriate methodologies to draw valid conclusions based on quantitative information"), had the lowest percentage of students passing. SLO 3 ("Students will be able to discern the validity and accuracy of an argument or conclusion derived from available numerical information") may also be in need of additional attention, even though it came closer to meeting the benchmark. Although there were some differences across disciplines, these are key areas for work in the future, as possibly there are more students struggling with these areas. One way this issue could be addressed is by discussing the quantitative reasoning learning outcomes ahead of time with students (perhaps at the beginning of the semester, as the learning outcomes are already listed on the syllabus). One instructor commented, "SLO2 and SLO3 are the areas where students must work from given information, use techniques that were taught in the course, and then produce a conclusion, which is usually more difficult than merely recognitive reasoning. These two areas will likely always produce the lowest scores. Making students practice those very skills many times prior to the assessment and doing so in ways that make sure they're not merely doing it by rote, but actually understanding what's happening. For example, group assignments where they have to explain their process to others."

Courses in Math scored the highest overall but did not do as well in the Conclusions category, a learning outcome where the Logic students performed well. These differences may be specific to the disciplines; however, the Logic instructor may be able to share some expertise. A meeting at the beginning of a semester to discuss interrater reliability between different disciplines (rather than just within disciplines, as happens now) might be useful for sharing expectations about what each score signifies. Within discipline interrater reliability is strong, with most disciplines represented here using a test bank for different sections of the same course (and in the case of Logic, only one professor teaches these courses, minimizing the lack of reliability across sections). Sharing rubrics, assignments and test questions across disciplines might also help alleviate any potential differences in scoring. Since this is the first time this version of Quantitative Reasoning has been assessed for SCHEV, this report can serve as a baseline for measurement and discussion moving forward.

Quantitative Reasoning is scheduled to be assessed again in 2023-24. For questions, contact the office of OIAE.

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Appendix 1: Sample Assessment Questions

PHIL 151B: Logic

The assessment took the form of selected questions on the final exam in the course. The questions were not distinguished from those that did not count for the purposes of assessment. The questions also counted as part of the final exam grade.

A total of 14 questions from the exam counted toward the assessment scores. Several questions counted for more than one learning outcome….

Part I. Probability. Show any work. When relevant either represent your answer as a fraction or a decimal to two decimal places.

1. We want to know the probability that we can stave off catastrophic climate change given we eliminate nearly all anthropogenic greenhouse gas emissions by 2050. Now, assume, through the use of computer models, we have the prior probability that we can stop catastrophic climate change, and it is .15 (Note: it also follows from this that we have the prior probability that we cannot stop catastrophic climate change of .85). And, these models tell us, given that we have stopped catastrophic climate change, there is a 95% chance we did in fact eliminate nearly all anthropogenic greenhouse gas emissions by 2050. This does in fact mean (according to the models) that there is a 5% chance we did not stop catastrophic climate change and yet did eliminate nearly all anthropogenic greenhouse gas emissions by 2050.

Part II. Statistical Reasoning. Show relevant work. Define any abbreviations. (9 pts)

2. Imagine this set of values represents the daily high temperature in degrees F for Fredericksburg, VA over the last 10 days: [70, 70, 67, 66, 60, 75, 83, 85, 85, 87]. Calculate the mean, median, mode, and standard deviation (for a sample) for this set of values. Which calculation gives us the average high temperature in Fredericksburg over the last 10 days? Show your steps for the standard deviation calculation. You can do the calculation by hand or link to a spreadsheet.

STAT 180: Introduction to Statistics

SLO 1: The SAT reading section has a mean of 500 and a standard deviation of 100. Lourdes scored a 600. At what percentile is her score? Draw and label a Normal distribution using the given parameters and showing Lourdes' SAT score. Then use the 68-95-99.7 rule to answer the question.

SLO 2: To estimate the level of mercury in fish in a certain region of the Pacific Ocean, researchers obtained a sample of 15 fish from that region. The sample showed a mean of 0.287 ppm Hg (parts per million of mercury) with a standard deviation of 0.069 ppm Hg. How should the researchers report their findings in the form of a 95% confidence interval for the mean mercury level of fish in this region? Write your answer as a complete sentence, worded as precisely as possible. (You may assume that these fish represent a random sample of all fish in the region, and that the population of mercury levels of all fish in the region is approximately normal in its distribution.)

SLO 3: A nationwide study done many years ago showed that college students get a mean amount of 7 hours of sleep. Recently a sleep-deprived group of Stats students decided to test whether the mean was less than that now. They obtained a random sample of 200 students whose mean amount of sleep was 6.7 hours. The standard deviation was 0.85, and the histogram was unimodal and slightly skewed. Perform a hypothesis test using 0.05 as the significance level. Check conditions and interpret your results in context.

SLO 4: A survey of 408 epidemiologists conducted during the Spring of 2020 (after the COVID 19 outbreak) indicated that 265 said it would be over a year before they would attend a sporting event, concert or play. Is this proportion more than 60%? Conduct the test using a 5% level of significance (make sure to include all five steps of a hypothesis test).