Quantitative Reasoning General Education Summer Working Group

Learning Outcomes and Implementation Plan

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Trends in Quantitative Reasoning in Higher Education

Over the past decade there has been an increasing emphasis on developing college courses that address the basic quantitative skills needed to be an informed citizen. The model followed by most universities that built the mathematics general education requirement on a standard "Mathematics for the Liberal Arts" course is a thing of the past, giving way to requirements centered around *quantitative reasoning* or *quantitative literacy*. Such courses de-emphasize abstract mathematical techniques in favor of giving students the ability to interpret and reason with numerical information. This is a nationwide trend in higher education in the United States spurred on by several factors, including the dearth of such instruction in secondary education and the increasing presence of numerical information—both reliable and not—in advertising, politics, social media, and other parts of students' lives.

This trend has been hard to ignore for those closely connected to quantitative disciplines. Though the effects have been most visible in the last 10 years or so, the movement has roots going back to the early 2000s. In 2004 the Mathematical Association of America published the report *Achieving Quantitative Literacy: An Urgent Challenge for Higher Education*[1], outlining the pressing need to put *numeracy* on par with *literacy* in order to educate a responsible and well-informed citizenry. This became a focal point for mathematics departments across the country, resulting in new general education courses with titles like "Quantitative Reasoning for Decision-making," "Math in Society," and "Math and Your Finances." One may now find such courses in the Virginia Community College System, at UMW, and in nearly all other public institutions in Virginia and across the country.

A brief history and the current state of this new "quantitative fluency" curriculum are nicely detailed in the article "Math Gets a Makeover" by Shannon Najmabadi, appearing in 2017 in the *Chronicle of Higher Education*[2]. In this article Najmabadi interviews several key players, giving persuasive arguments for this reform. Chief among them is the need to provide students real-world numeracy skills that will be directly relevant to their lives after graduation, content and skills that students of *all* majors will need, not just those who are STEM-focused. This is best achieved in context and through different disciplines, these connections to areas outside of "pure" mathematics giving the proof that "this stuff is useful." Relating the material to actual parts of students' lives furthers these connections, enhancing student retention (and appreciation) of the material.

[1] Available online at https://www.maa.org/sites/default/files/pdf/QL/NTE62.pdf.
[2] Available online at https://www.chronicle.com/article/Math-Gets-a-Makeover/239789.

And it is clear why we have the responsibility to help our students develop these skills. It is an unfortunate fact that university students are not as well-prepared in basic mathematics and quantitative literacy as they once were, through no fault of their own. Incoming students frequently struggle with basic concepts like fractions, ratios and proportions, percentages, and interpreting graphical data[3]. Given the preponderance of (potentially unreliable) information on the internet—experienced by anyone with a social media presence—it is a simple matter to create a healthy list of questions best answered by a quantitative analysis:

- Is there really a link between autism and vaccinations?
- Should I defer my student loans? What are the advantages or penalties for doing so?
- If a medical test has a 10% false-positive rate, should I be worried about my results?
- Do recent turbulent weather events give evidence for climate change, or is this explained by natural fluctuations?
- Does the data indicate a gender wage gap in Silicon Valley?
- Why did this computer model give the wrong prediction on the election winner?

Questions like these will be unavoidable for our students. These are nuanced questions with multiple facets based in numerical information. Addressing such issues in real-world contexts requires our students to develop analytic and critical thinking skills, reasoning deductively with numerical evidence toward a justifiable conclusion. For these reasons, we have a responsibility to equip our students with highly focused skills in quantitative reasoning.

Learning Outcomes

This working group consulted multiple sources in considering the learning outcomes for the quantitative reasoning category. The most compelling source is the 2014 Susan Elrod[4] article "Quantitative Reasoning: The Next 'Across the Curriculum' Movement" appearing in the *Peer Review* magazine of the American Association of Colleges and Universities. There, Elrod argues that the skills and habits of mind developed in QR courses must be contextualized within an academic discipline or a facet of society, always toward the goal of understanding data and drawing conclusions within those contexts. She draws a distinction between QR courses and mathematics courses, emphasizing that QR courses are focused on the *meanings* of calculations and analysis, not just the techniques and machinery (as important as they may be).

[3] In fact, this deficiency is precisely the reason for the existence of CHEM 101 at UMW.

[4] At press time, Elrod was Interim Provost and VPAA at California State University-Chico. Her article is available online at https://www.aacu.org/peerreview/2014/summer/elrod.

In addition, Elrod gives sample learning outcomes for QR courses, including those at the University of Virginia. This led us to examine QR general education requirements and outcomes at a sampling of other Virginia institutions. Our findings for five state institutions are detailed in the appendix following this report.

In considering all of the aforementioned sources, there is a clear and repeated emphasis on understanding numerical information, using these skills to reach conclusions and to verify the findings of others, and doing all of this in the context of other disciplines. As the QR requirement at UMW as of the 2020-2021 academic year will require *only one* course of each student—representing a narrowing of the current system—we likewise feel a more focused set of outcomes will have the most benefit to our students in becoming informed and engaged citizens. Our recommendations are as follows:

Quantitative Reasoning Student 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 contemporary issues in multiple disciplines or aspects of society.

Implementation

As this is not a completely new general education requirement, much of the curricular "infrastructure" is already present. In order to give a fair assessment to all courses, the slate should be wiped clean with the QR category initially empty. It is almost a certainty that some current QR courses will not meet these new outcomes as they stand *without modifying the course content.* In some cases only small changes to the way a course is taught may suffice, but such changes can only benefit our students by updating the course and making it more relevant. At the same time, it is clear that many current QR courses will meet these new QR outcomes with no substantive changes. Given that the QR requirement is now down to a single course, it is clear that we already have a sufficient number of QR courses for meeting our students' four-year graduation and scheduling needs.

A call for proposals should go out as early as possible, and to expedite their consideration we recommend a clear-cut proposal form. We have drafted a QR-specific proposal form which should be easy to parse for a potential course's satisfaction of all learning outcomes and their eventual assessment. A copy of this draft form is attached at the end of this report.

Assessment

Given that this requirement is not entirely a new invention, multiple departments and disciplines deliver QR courses, and the content is already naturally quantitative, there is no need to alter significantly our current QR assessment plan. The current scheme has the nice feature of being maximally flexible to the various departments involved and this should be maintained. Below we give an assessment plan for the new QR requirement, written in the same format as our current standards.

Assessment Method
Each program will develop appropriate assessment methodology for determining the proficiency level of students in each of the four learning outcomes. For easy analysis, it is recommended that all four outcomes be scored on the same scale. For courses with enrollment higher than 30, faculty may report assessment data on 50% or more of students, randomly selected from those enrolled in the course. Each student should be scored on each learning outcome based on a maximum value determined by the program. All faculty teaching the same course ideally (but not necessarily) should use the same assessment approach/items and the assessment should be done toward the end of the semester (e.g. final writing assignment or final exam). Faculty are encouraged to administer the assessment as part of an existing graded assignment so that students will put adequate effort into the assessment. By the last day grades are due each semester, submit your results to the Office of Institutional Analysis and Effectiveness (OIAE) using the template Excel sheet for QR. Some departments may choose to coordinate efforts through the department chair (especially those assessing multiple goals), in which case the chair will forward all results to OIAE.

Academic departments/programs are not required to analyze the general education assessment data collected. OIAE will aggregate and report on the university wide assessment data.

Quantitative (QR) Assessment Rubric

Instructions: Please record the score for each student for each SLO in an Excel spreadsheet using the scale below. Individual disciplines may develop this template further to meet their discipline's specific understanding of these topics.

Learning Outcome	Excellent (A) - 4	Good (B) - 3	Fair (C) - 2	Unacceptable (D/F) - 1
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 contemporary issues in multiple disciplines or aspects of society.				

Appendix: QR at Other Virginia Institutions

For the purposes of comparison and reference, we give below the descriptions and student learning outcomes for the quantitative reasoning requirements at a sample of public institutions in Virginia (together with the courses meeting their QR requirement). This includes competitors such as Christopher Newport University as well as one of our closest partners, Germanna Community College. All information was extracted verbatim from current academic catalogs.

Germanna Community College

A person who is competent in quantitative reasoning possesses the skills and knowledge necessary to apply the use of logic, numbers, and mathematics to deal effectively with common problems and issues. A person who is quantitatively literate can use numerical, geometric, and measurement data and concepts, mathematical skills, and principles of mathematical reasoning to draw logical conclusions and to make well-reasoned decisions. Degree graduates will demonstrate the ability to:

a. use logical and mathematical reasoning within the context of various disciplines;
b. interpret and use mathematical formulas;
c. interpret mathematical models such as graphs, tables and schematics and draw inferences from them;
d. use graphical, symbolic, and numerical methods to analyze, organize, and interpret data;
e. estimate and consider answers to mathematical problems in order to determine reasonableness;
f. represent mathematical information numerically, symbolically, and visually, using graphs and charts.

Courses meeting the QR requirement: Any MTH course at 154 (Quantitative Reasoning) or higher.

Longwood University

An understanding of mathematical thought and the ability to conceptualize and apply mathematical logic to problem solving.

NOTE: Students who complete Calculus (MATH 164, 261, or 267) are exempted from this goal.

Outcomes

Students will:

- Understand how mathematical and/or statistical models can be used to study real-world situations.
- Understand the limitations of and assumptions behind typical mathematical models

- Use mathematical and statistical analysis to interpret such models by testing. hypotheses, making predictions, drawing conclusions, checking results for plausibility, and finding optimal results.
- Understand when technology might be helpful in mathematical or statistical analysis and apply technology when appropriate.

Courses meeting the QR requirement:

- CMSC 121 - Introduction to Computer Science (3 credits)
- MATH 114 - Mathematics for the Consumer (3 credits)
- MATH 121 - Functions and Graphs (3 credits)
- MATH 150 - Mathematics And (3 credits)
- MATH 171 - Statistical Decision Making (3 credits)
- FINA 250 - Personal Finance (3 credits)

James Madison University

After completing **Cluster Three: The Natural World**, students should be able to meet the following objectives:

- Describe the methods of inquiry that lead to mathematical truth and scientific knowledge and be able to distinguish science from pseudoscience.
- Use theories and models as unifying principles that help us understand natural phenomena and make predictions.
- Recognize the interdependence of applied research, basic research, and technology, and how they affect society.
- Illustrate the interdependence between developments in science, social and ethical issues.
- Use graphical, symbolic, and numerical methods to analyze, organize, and interpret natural phenomena.
- Discriminate between association and causation, and identify the types of evidence used to establish causation.
- Formulate hypotheses, identify relevant variables, and design experiments to test hypotheses.
- Evaluate the credibility, use and misuse of scientific and mathematical information in scientific developments and public-policy issues.

Quantitative Reasoning: (part of this "cluster")

Students build mathematical models of systems and learn to understand, interpret and analyze data that is numerical in nature.

Courses meeting the QR requirement:

- ISAT 151. Analytic Methods I: Topics in Applied Calculus for ISAT
- ISAT 251. Analytic Methods III: Topics in Statistics for ISAT
- MATH 103. The Nature of Mathematics
- MATH 105. Quantitative Literacy and Reasoning
- MATH 107. Fundamentals of Mathematics I
- MATH 205. Introductory Calculus I
- MATH 220. Elementary Statistics
- MATH 231. Calculus with Functions I
- MATH 235. Calculus I

George Mason University

Quantitative Reasoning Learning Outcomes:

1. Students are able to interpret quantitative information (i.e., formulas, graphs, tables, models, and schematics) and draw inferences from them.
2. Given a quantitative problem, students are able to formulate the problem quantitatively and use appropriate arithmetical, algebraic, and/or statistical methods to solve the problem.
3. Students are able to evaluate logical arguments using quantitative reasoning.
4. Students are able to communicate and present quantitative results effectively.

Courses meeting the QR requirement:

- CDS 292 Introduction to Social Network Analysis
- HNRT 125 Applied Quantitative Reasoning
- MATH 106 Quantitative Reasoning
- MATH 108 Introductory Calculus with Business Applications
- MATH 110 Introductory Probability
- MATH 111 Linear Mathematical Modeling
- MATH 113 Analytic Geometry and Calculus I
- MATH 115 Analytic Geometry and Calculus I (Honors)
- MATH 124 Calculus with Algebra/Trigonometry, PartB
- MATH 125 Discrete Mathematics I
- SOCI 313 Statistics for the Behavioral Sciences
- STAT 250 Introductory Statistics I

Old Dominion University

Develop mathematical and information literacy.

1. Develop basic mathematical competence.
2. Develop information literacy competence.

Courses meeting the QR requirement:

- MATH 101M An Introduction to Mathematics for Critical Thinking
- MATH 102M College Algebra
- MATH 103M College Algebra with Supplemental Instruction
- MATH 162M Precalculus I
- STAT 130M Elementary Statistics

GENERAL EDUCATION COURSE PROPOSAL—EXPEDITED FORM—QUANTITATIVE REASONING

UNIVERSITY OF MARY WASHINGTON

Use this form to submit **EXISTING** courses for review to initially populate Quantitative Reasoning (QR) for the new General Education curriculum beginning the Fall of 2020. **Submit this form and the course syllabus to XX XX at xx.xx@umw.edu.**

Course Discipline and Number: Click here to enter text.

Course Title: Click here to enter text.

Submitted by: Click here to enter text. **Date:** Click here to enter text.

Frequency of offering: ☐ Fall ☐ Spring ☐ Yearly ☐ Alternate years

Does this course currently have any prerequisites? Yes ☐ No ☐

If yes, list the prerequisites here:

Signature of Proposer: _____ Date: _____

Signature of Department Chair: _____ Date: _____

This proposal consists of two parts: (1) a rationale regarding the course content's satisfaction of all four learning outcomes (listed below) and (2) a sample of assignments or questions from the course that may be used to assess the learning outcomes. Please fill out both sections in their entirety.

(1) RATIONALE: Using the space below, explain why this course should be approved for the QR designation by discussing how EACH of the learning outcomes will be fulfilled through the course content.

(2) ASSESSMENT: Using the spaces below, explain how each of the learning outcomes will be assessed. Include sample assignments or questions that may be used to assess each outcome in the dedicated spaces below.

Learning Outcome 1: Students will demonstrate the ability to produce and interpret quantitative information in various forms such as graphs, equations, diagrams, etc.

Learning Outcome 2: Students will use appropriate methodologies to draw valid conclusions based on quantitative information.

Learning Outcome 3: Students will be able to discern the validity and accuracy of an argument or conclusion derived from available numerical information.

Learning Outcome 4: Students will apply quantitative techniques to address contemporary issues in multiple disciplines or aspects of society.