Quantitative reasoning in higher education: The 5C Model

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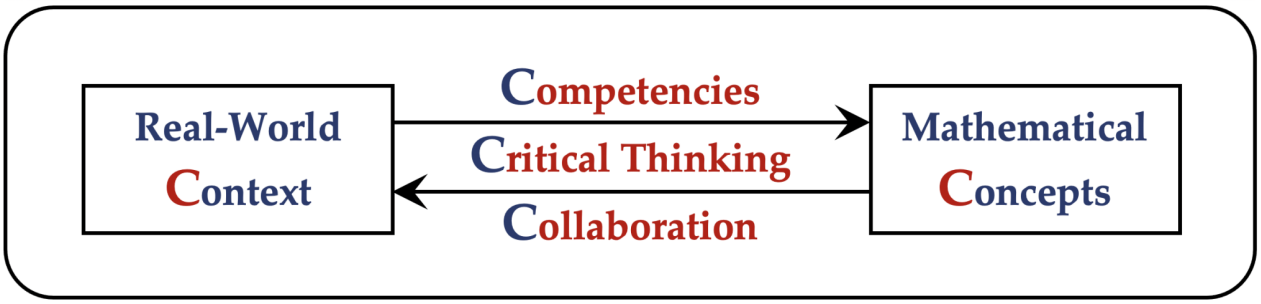

Figure 1. The 5C model of student engagement in QR. Critical thinking is the heart of QR. QR Competencies and student Collaboration help students connect real-world Contexts to mathematical and statistical Concepts to make decisions about meaningful personal and professional issues.

Quantitative reasoning enhances and lengthens lives. Professor Gregory Foley of Ohio University discusses how his team is improving QR instruction in U.S. higher education

Quantitative reasoning (QR) is essential in today's world. This learned human capacity improves health and financial decisions and is linked to better outcomes and longer life. For example, we humans benefit from learning how to answer questions such as:

- How likely is a positive COVID test to be a true positive?
- What is my best path to a financially secure retirement?

However, traditional mathematical education – even at the tertiary level – is theoretical and typically does not provide opportunities for students to think critically about these kinds of real-life questions.

Two Royal British reports – the 1959 Crowther Report and the 1982 Cockcroft Report – heralded numeracy as essential to individuals' daily lives. In the decades since these reports, there have been efforts around the globe to assess and bolster school mathematical literacy and adult numeracy. Building on these efforts, research and development in numeracy education is growing at the tertiary (or higher) education level in South Africa, the United Kingdom, and the United States.

This article focuses on entry-level QR courses in U.S. higher education, especially efforts to improve QR teaching and learning in Ohio and across the United States.

The centrality of critical thinking

A tertiary course in QR develops students' ability to understand a genuine situation and to use mathematics and statistics as tools to pose and answer questions about the situation. Consequently, as shown in Figure 1, critical thinking is the heart of our team's approach to QR. Critical thinking "involves interrogating an object of study to conceptualize and analyze it in order to reach a conclusion or judgment about it."

Genuine contexts

Here is an example of a situation that students would be asked to investigate in a QR course:

As of 2024, student loan debt in the United States totaled about US$1.8 trillion.

The first step is for students to brainstorm and develop questions to ask about this issue: What is the trend over time? What is the average debt per student? How can an individual's debt be paid off? Different groups might take on different aspects of the problem to explore, or the entire class could agree on one facet of this issue to examine. While investigating each such problem, the students would engage in six types of behavior.

QR competencies

The critical thinking of QR involves six types of cognitive processes. In a QR course, students:

- Interpret. Glean and explain mathematical information presented in various forms: sentences, tables, graphs, diagrams, and equations.
- Represent. Convert information from one of these representational forms into another.
- Calculate. Perform arithmetical, mathematical, and statistical computations.
- Assume. Recognize, make, and evaluate underlying assumptions in estimation, modeling, and data analysis.
- Analyze. Develop conclusions based on quantitative information and critical thinking.
- Communicate. Organize, contextualize, synthesize, and present thoughts and processes using mathematical and statistical evidence.

QR instructors encourage and monitor student progress on investigations using these competencies as a framework, and they watch for long-term student growth in these areas.

Student collaboration

Our team's view of student learning in a QR course is founded on two interactive theories of learning that support one another – constructivism and social constructivism. Students' engagement in thought-provoking, context-rich tasks gives them the opportunity to

construct knowledge based on their individual experiences with such tasks. Some QR tasks may be beyond the individual reach of students – but within the collective reach of a small group of students working together.

By collaborating with peers, students can socially build cognitive structures through interactions with each other. Collaboration gives learners the opportunity to communicate their thinking and make it seen and heard by others, which scaffolds critical thinking, analysis, and communication. Hence, our team promotes instruction that is student centered, active, and collaborative.

Flexible content

A QR course typically employs the concepts of ratio, proportion, and percent, as well as probability, statistics, and mathematical modeling. The specific topics, however, vary greatly from one college or university to the next and from instructor to instructor. Regardless, the content should be flexible. It should align with the real-life contexts being investigated. In a QR course, students represent their thinking using natural language, tables, graphs, and formulas. Technological tools play an important role as students represent their work using word- processing, spreadsheet, graphing, and presentation software.

QR courses: Overcoming obstacles

Despite providing students with a meaningful mathematical experience, QR courses face many challenges. Many students in these courses dislike or fear mathematics and have avoided it in the past. Due to the novelty of QR courses, many advisors are hesitant to recommend these courses to students. Perhaps most importantly, today's mathematics teaching workforce is used to teaching techniques-centered courses and is ill-equipped to teach a course focused on student reasoning and communication. Consequently, to be successful in teaching QR, most instructors need professional development and ongoing collegial support.

Our QR professional development network

Since 2022, Foley has collaborated with Lee Wayand of Columbus State Community College to lead QuantNet. This U.S. National Science Foundation project is creating statewide professional development networks to support the effective teaching of QR courses. So far, the project has created a QR network of 75 instructors across 14 colleges and universities in Ohio.

In July 2025, the project will extend its current Ohio-based network and invite teams of QR instructors to establish similar networks in other states.

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