

The Quantitative Thinking Requirement

*David Blaney, Beth Cleary, James Heyman, Daniel Kaplan, Gary Krueger, Karl Wirth
August 17, 2005*

Quantitative Thinking Requirement:

Students will take one or more courses with a Q1, Q2, or Q3 designation. (The number indicates how broadly the course covers quantitative concepts.) A single Q1 course completely satisfies the requirement, but some students will prefer to satisfy the requirement by taking a Q2 course together with any other Q2 or Q3 course, or by taking three Q3 courses.

Rationale:

Developing quantitative thinking skills an essential component of a liberal education. Critical thinking incorporates both qualitative and quantitative evidence and evaluation. In some fields of study, quantitative approaches play a central role, while qualitative thinking dominates other fields. Despite these differences in emphasis across fields, critical thinking skills and habits of mind learned in one area often carry over and reinforce those learned in other areas. It is for this reason that the breadth of experience associated with liberal arts education prepares students effectively to be active participants and leaders in government, civil society, business, and academia.

Many policy debates, scientific discussions, and personal and organizational decisions involve making judgments about claims made with quantitative evidence. [See Appendix 2 for some examples.] To evaluate these claims, the individual must have some basic familiarity with counting, measurement, and statistical analysis. Equally important is the capacity to ask and answer questions in manners appropriate to these quantitative tools, and to understand when and where the use of quantitative tools is appropriate and when and where it is not. The purpose of the QT requirement is to ensure that students have the opportunity to develop such capacities. Students should learn a group of related approaches to collecting, interpreting, and presenting information about the world built out of relatively simple and familiar numerical, statistical, and logical skills. These topics arise in a wide range of areas, and we invite faculty from a range of disciplines to teach courses that contribute to QT.

Learning Objectives:

Students who satisfy the QT requirement should develop the ability to:

- Describe the world quantitatively
- Evaluate sources and quality of data
- Distinguish association from causation
- Understand trade-offs, uncertainty and risk
- Use estimation and modeling to evaluate claims and test theories.

These broad topics are described in more detail below.

- **Describing the World Quantitatively:** Much of quantitative thinking involves quantitative or statistical descriptions of social and natural phenomena. This includes descriptions of patterns and variations and rates of change, such as linear or exponential growth. Understanding descriptive statistics and the various modes of presentation of quantitative data is central. Students should be able to distinguish when quantitative approaches are appropriate and when they are not.
- **Evaluating Sources and Quality of Data:** Students of quantitative thinking should also understand the sources of data, including the processes of collecting or producing data. This may involve understanding how to assess the reliability and validity of measurements and elements of probability and sampling, including sources of bias and error.
- **Association and Causation:** The quantitative thinker knows the ways that associations between factors are established by observation, experiment or quasi-experiment. It is important to be able to establish the meaning of an association or correlation and learn the protocols for weighing the statistical significance and theoretical importance of findings, including inferring causation.
- **Trade-Offs:** Most decisions, whether public or private, individual or societal, may be thought of as involving conflicting goals. Much of the debate on public issues involves disagreement about the value of the different goals. Where there are conflicting goals, quantitative thinking offers techniques for weighing the relative impact of policy options. While there rarely is a single correct outcome in the face of such conflicts, the quantitative thinkers can bring measure and balance to policy discussion.
- **Uncertainty and Risk:** Few things in life are certain; decisions and debate often revolve around unknowns. The quantitative thinker possesses skills that can be used to assess, compare and balance risks, and understands the limits and strengths of these techniques. The quantitative thinker knows that, in the face of the unknown, if not the unknowable, we often rely on conditional statements and probabilities in making decisions and can evaluate conclusions drawn from conditional statements.
- **Estimation, Modeling, and Scale:** The quantitative thinker understands that quantities vary over huge ranges; ‘big’ and ‘small’ are not absolute notions but depend on context or scale. Quantitative thinkers appreciate the value and limitations of abstracting out detail—constructing models—and that the sensitivity of model results to assumptions can and should be reported along with the model results.

Criteria for Designation as a “Q” course:

Macalester courses that incorporate substantial contact with quantitative thinking are identified with a Q designation. Depending on both the breadth and intensity of this contact, the course is designated Q1, Q2, or Q3. The number indicates the number of courses at that level that a student

would need to completely fulfill the requirement. We emphasize that these labels do not specify the difficulty of the course: most Q1 courses will have no prerequisites, while many advanced courses in the natural sciences may be Q3 courses.

Each semester, the QT Steering Committee will publish a list of the Q designations of certified courses. The Q designations of courses will normally be reviewed each time they are offered, and the designations will be made on a section by section basis. The QT Steering Committee will apply standards of both breadth and intensity of coverage of the quantitative components listed above. The general guideline for designation is as follows:

- Q1** These courses should cover nearly all of the central quantitative topics. They should have no quantitative prerequisites. Among existing courses, introductory statistics and principles of economics perhaps come closest to this ideal. Faculty from the QM4PP project are working on developing a new 4-credit course that would be even broader. This is expected to be introduced in 2007-8.
- Q2** At least half of the material covered in Q2 courses will focus on quantitative topics, and these will cover the majority of the central topics listed above. The range of application may be narrower than in Q1 courses. Possible examples might include methods courses in the Natural and Social Sciences that discuss experimental design and statistical analysis.
- Q3** Some range of the quantitative components are touched on in Q3 courses, and quantitative thinking elements represent at least 25% of the overall material covered in the course. These will place quantitative thinking into the broadest range of contexts. We envision possible courses in media analysis, rhetoric, ethics, environmentalism, and policy analysis, to name a few, in addition to the existing natural and social science courses that already offer substantial quantitative content.

The QT Steering Committee

A QT Steering Committee will be established as a subcommittee of EPAG, comprised of a member of EPAG and additional members appointed by the Provost. The responsibilities of the committee are to:

- Identify courses as satisfying the QT.
- Arrange a yearly half-day faculty development workshop for Q instructors to help orient faculty teaching new QT courses, to disseminate ideas and materials relating to teaching QT, and to promote communication among participating faculty.
- Develop and update of instruments to be used for assessing students' mastery of QT, both for summative evaluation and to provide feedback to instructors.
- Assist faculty interested in developing Q courses or including quantitative components in existing courses.
- Report to EPAG and the faculty on the QT program and whether it is meeting its goals.

- Aid the Registrar in providing timely information to students about what sections satisfy the QT and information to students and advisors to guide their choices with respect to QT.
- Consider and rule on requests from students for alternative ways to satisfy QT including transfer students who seek a waiver of QT for comparable work done elsewhere.

Further notes about the Quantitative Thinking Requirement

We acknowledge that this proposed requirement is structured somewhat differently than other requirements currently in the curriculum. This section seeks to explain our reasoning for the proposed structure and to highlight additional issues that we think the faculty ought to consider before voting on this specific proposal.

Why are there three levels of Q courses? Why is a single type of course not enough? To the extent possible, our general education requirements should preserve student choice. The Q1-Q3 system we propose gives students many different ways to acquire Quantitative Thinking skills. This system will also greatly broaden the range of quantitative courses available to students. Additionally, it will help to involve as many faculty as possible into quantitative education at Macalester, and induce development of quantitative courses by faculty who might otherwise not consider adding quantitative components to their current offerings.

Why are courses approved on a section-by- basis versus a more standard course approval approach ? While we recognize the difficulties in implementing section-by-section approval, we think it has some important advantages in inducing faculty participation in the QT program. Approval at the level of individual sections will facilitate faculty development of quantitative courses by allowing individual faculty to create Q courses without requiring faculty teaching alternate sections of the same courses to do the same. A comprehensive list of the specific sections that qualify for Q designation will be published before the registration period for each semester. We note that the College currently does this for in a few cases: for example, some sections of courses in English satisfy the domestic diversity requirement while others do not.

Why should the Q designation of a course be reviewed each time the course is offered? The content and emphasis of most courses evolve over time. Regular review will help to sustain the QT program by ensuring that courses are re-examined on a regular basis, especially as course instructors change. In order for a requirement is to remain a viable component of the curriculum, we must have regular oversight of its implementation.

What new resources will be required to implement this proposal ? It is our belief that sufficient QT courses can be offered with existing FTE. Currently, there are approximately three courses in the curriculum that will likely receive Q1 designation and would hence satisfy the requirement in a single course. In the 2005 graduating class these courses served approximately 350 of the 450 graduates. Taking together the courses in our current curriculum which will likely receive Q designation with minor revision and a small number of additional courses, a wide variety of choices will be available to students to fulfill the QT requirement. Resources will be required to support course innovation, both for

smaller revisions and the piloting of new courses, and for professional development and support activities organized by the Steering Committee.

When should students fulfill the QT requirement? The best time to take Q courses depends on the student's interests. Many students in the natural and social sciences will take several Q courses as they progress through their majors; the sequence judged appropriate for the major is also appropriate for quantitative thinking. A student who takes several Q3 courses is encouraged, but not required, to spread these out through his or her college career, since repeated exposure over time is expected to reinforce the building of quantitative thinking skills. A student who plans to take a single (Q1) course is advised to take that course in the sophomore year. Since quantitative thinking is an aspect of critical thinking, the impact of a Q1 course will be enhanced by earlier coursework that cultivates critical thinking skills.

Appendix 1: Proposed Catalog Copy

The Quantitative Thinking graduation requirement (QT) ensures that every student is exposed broadly to a set of critical thinking skills of importance to individual and civic discourse and decision making. Quantitative thinking consists of sophisticated reasoning built mostly out of relatively simple and familiar numerical, statistical, and logical skills.

Students satisfy the requirement by taking one or more courses with a Q1, Q2, or Q3 designation. (The number indicates how broadly the course covers quantitative concepts.) A single Q1 course completely satisfies the requirement, but some students will prefer to satisfy the requirement by taking a Q2 course together with any other Q2 or Q3 course, or by taking three Q3 courses. Since quantitative thinking skills are enhanced by repeated exposure, a student who satisfies the QT requirement by taking two or more courses is encouraged, but not required, to take them in different semesters.

Some of the Q courses are offered every semester or every year and can be identified from the course number. Many other Q courses are offered on an occasional or trial basis and, in some cases, only certain sections of a course will carry the Q designation. A comprehensive list of the specific sections that qualify for Q designation is published before the registration period for each semester. Only designated sections count toward fulfilling the QT requirement.

A detailed description of the requirement, including the list of qualified courses and suggestions about effective ways of designing an education for quantitative thinking, is available at www.macalester.edu/qt.

Appendix 2: Expressions of Quantitative Thinking: Examples from Current Issues of Public Concern

None of the questions below have a single, provably correct answer. All of them involve judgment, values, and ethics. All of them are strongly informed by quantitative information, most of them involve balancing competing goals. The purpose of an education for quantitative thinking is to enable students to make informed judgments about such issues and to communicate those judgments and the reasoning behind them in discussion and debate.

One way to address global warming is to use more nuclear and hydroelectric power. Yet nuclear power imposes risks and hydroelectric dams can have serious environmental consequences. How do we judge to what extent it is worthwhile to accept these risks and consequences?

Breast cancer kills approximately 1 percent of all women in the US. Affordable screening tests (e.g.,

mammography) are available. Should insurance companies be required to pay for mammography for all women? If my insurance company doesn't cover it, should I pay for the test myself?

Opponents of immigration often claim that immigrants force down wages of US workers, proponents say that immigrants take jobs that Americans aren't willing to

do. Both arguments seem plausible. How should I evaluate these claims?

The federal government might raise Social Security taxes. I don't want to pay more taxes, but I would like to benefit from Social Security. What's a reasonable and responsible tax rate?

Government statistics show that, as a group, women continue to earn less than men. How can I assess whether this reflects discrimination or different lifestyle choices that men and women tend to make?

Mad-cow disease has been linked to human deaths. The US Dept. of Agriculture restricts testing for mad-cow disease to a very small fraction of cattle. Is it safe to eat beef?

Some people want to take public money to give vouchers to students to study in private schools. These people claim that the private, generally religious schools produce better educational outcomes for the same money, and back up these claims with standardized test results from pilot programs. Should I support an expansion of these programs?

SUVs contribute to global warming because of their poor fuel economy. Should I support attempts to tax SUVs? Should I similarly support a ban on college students flying south during Spring break?

Would a \$1 per gallon tax on gasoline derail the economy? Would it have a substantial impact on gasoline consumption?

Might health care costs double in the next five years, or are such claims simple fear-mongering?

There is a consensus, after 9/11, that some loss of privacy for increased security is appropriate, for instance more careful baggage screening at airports. There is considerable disagreement about how far this should go. How does one decide to what extent a loss of privacy is appropriate? Is there any circumstance in which ethnic screening might be legitimate?

Are the risks of mass flu vaccination worth the benefits? How do you measure the risks?

The American College of Pediatrics supports a requirement for child-safety seats on airplanes. Airlines and travel agents oppose such a requirement because it would make travel more expensive. How do I balance their respective concerns?

Private accounts in Social Security would increase payments without raising taxes, yet they are acknowledged to increase risk. How do I know whether this increased risk means that private accounts are bad public policy? Could it be true that a 1 percentage-point increase in social security taxes would save the system?

Eyewitness ID and police lineups have been used to convict many criminals, yet civil rights advocates say they are not reliable. Should they continue to be used?

Appendix 3: Comparison to Other Colleges

Under the new requirements passed in outline by the faculty in April 2005, Macalester will have a distribution requirement that, in terms of credit hours, is similar to most of our peer schools.

Of the 39 other schools in our standard 40-school peer group, 24 have a specific requirement that students take a quantitative course. Five additional schools have a 3-course undifferentiated natural-science/math requirement. Four more schools have a 2-course undifferentiated requirement (matching Macalester's old requirement). A further five schools have an "advisor-based" model, with no specifically mandated distribution requirements. Of the 34 schools with distribution requirements, only one, Franklin and Marshall, has neither a quantitative requirement nor includes math in a general science requirement. Some schools allow students to satisfy their quantitative requirement with an AP or similar test; we found four such schools, but there may be others where the information does not appear on web sites or in catalogs.

In terms of the content of courses satisfying a quantitative requirement, in most of the 24 schools with an explicit quantitative requirement the emphasis is on mathematics, often with specific math-department courses listed. In much of the College's planning, we pay particular attention to our close-comparison group: Carleton, Grinnell, and Oberlin.

Carleton, which currently has a 3-course undifferentiated science/math requirement, recently received a US Dept. of Education FIPSE grant to use students' writing portfolios to develop an effective campus-wide quantitative reasoning curriculum. They have stated three basic learning goals:

Inquiry: Students should recognize implicit and explicit quantitative claims in discourse and should develop the inclination to evaluate and test such claims critically. They should develop the habit of mind to apply quantitative reasoning electively in a wide array of appropriate contexts.

Knowledge: Students should develop a firm grounding in the procedures and methods of quantitative reasoning. They should become knowledgeable about and skilled in data analysis. They should also appreciate basic

physical, biological, historical, demographic, and social quantities and magnitudes.

Reasoning: Students should employ quantitative reasoning soundly in decision-making and problem solving. They should appreciate choices that could be made in the conduct of quantitative analysis and in the representation of quantitative information. They should weigh those choices in light of appropriate conventions and of social and ethical considerations associated with data collection and uses of data.

Oberlin has a 1-course requirement which can be satisfied with one full-quantitative course or two half-quantitative courses. Almost all of the full-quantitative courses are in mathematics, physics, chemistry, or psychology research methods. Here is their description:

The Oberlin College faculty adopted in 1987 a Quantitative Proficiency Requirement for the BA degree. The requirement promotes quantitative proficiency and provides a focus for a College-wide commitment to extend and promote the teaching and application of quantitative skills. The faculty views the Quantitative Proficiency Certification Requirement in terms of its goals, not in terms of a narrowly defined set of mathematical or computational skills. Thus, the requirement is intended to urge students to develop the ability to apply logical thinking to complex problems, to encourage a deeper understanding of numbers, to foster mathematical modeling and incorporating the computer as a potent quantitative tool in many disciplines, and to demonstrate how quantitative practices and techniques are essential to the understanding of important societal issues.

Grinnell has an advisor-based model with no specific distribution requirements. In describing this system, they write, "For more specific guidance in planning an academic program, a student should review the six areas outlined below." These areas are: Writing and reading, foreign language, natural sciences, quantitative reasoning, human behavior and society, creative expression and the arts. About quantitative reasoning, they write:

Quantitative reasoning, with emphasis on mathematical models and methods above the secondary-school level, aids in the expression of hypotheses, processes, and theoretical relations. A course in statistics can be helpful for all students, and particularly for those who might work in the social and behavioral sciences. Studies in computer science offer valuable exposure to principles of logic and problem-solving paradigms.

Macalester is widely regarded as a leader in developing a meaningful alternative to a traditional mathematics requirement. Over the past four years, Macalester developed a prototype quantitative thinking program, Quantitative Methods for Public Policy,

directed by David Bressoud and involving the active participation of a dozen or so faculty from various departments and divisions. About 400 Macalester students took the QM4PP course, which has been offered each semester for the past three years. Many of the ideas in the current QT proposal are drawn from QM4PP, although the administrative structure is completely different. The QM4PP program attracted national attention. Several workshops on quantitative reasoning were held at Macalester, faculty from Mac have described QM4PP at national meetings, other colleges have sent observers, and Macalester received funding from the US Dept. of Education FIPSE program and the National Science Foundation totaling almost one-half million dollars