

Review of the Quantitative Reasoning Requirement, September, 2005

Rationale for the Quantitative Reasoning Requirement from the Curricular Review Committee Report, 2000:

When the Kenyon academic departments and programs were queried about educational goals for our graduates, the most common response was that students should either have facility with quantitative reasoning or have taken a course in mathematics (92% of respondents). In spite of this perception of importance among the faculty, 30-35% of our graduates avoid all courses with substantial exposure to quantitative reasoning. This negatively impacts students' ability to use quantitative information; in the Academic Profile (published by ETS), Kenyon students at the end of their sophomore year were much less proficient in using mathematical data than in reading and critical thinking skills (20% were in the lowest proficiency categories for quantitative skills compared to 9% for reading and critical [verbal] thinking). Why is this a problem?

Quantitative reasoning is an important kind of critical thinking, especially in our technological world. We intentionally use the term quantitative reasoning to indicate numerical and logical tools and the use of these in creating and interpreting arguments, so our recommended requirement goes beyond mere arithmetic proficiency.

The importance of numerical arguments for understanding both academic disciplines and current events is widely recognized. Technological advances in computing and communication have created a new reliance on quantitative information and inference which is unlikely to diminish. According to Lynn Steen (1997), "As information becomes ever more quantitative and as society relies increasingly on computers and the data they produce, an innumerate citizen today is as vulnerable as the illiterate peasant of Gutenberg's time."¹ Recommendations from the Subcommittee on Quantitative Literacy Requirements of the Mathematical Association of America include treating quantitative literacy as a necessary goal for baccalaureate graduates,² and suggest that every college graduate should be able to apply simple mathematical methods to the solution of real-world problems.² At a minimum, our graduates would be poorly served by an education that allows them to avoid all courses emphasizing quantitative reasoning, yet this is too common at Kenyon.

Requirements for quantitative reasoning have been adopted by many colleges and universities, including Dickinson, Harvard, Oberlin, Pomona, and Rollins. In their programs, students must pass an exam on data interpretation,² or take courses in statistics or in quantitative reasoning.² We envision a requirement that can be satisfied by taking courses from several departments, although the Mathematics Department will be the primary home² for courses in quantitative reasoning. Other departments currently teaching courses that are likely to fulfill this requirement include Biology, Chemistry, Economics, Philosophy, Physics, and Psychology. Courses fulfilling the quantitative reasoning requirement must either emphasize the ability to analyze, interpret, and assess

¹ Steen, Lynn Arthur. 1997. Preface: the new literacy. In Steen, Lynn Arthur (ed). *Why Numbers Count: Quantitative Literacy for Tomorrow's America*. College Entrance Examination Board, New York.

² Their full report can be found through the Internet: http://www.maa.org/past/ql/ql_toc.html.

arguments that use numerical information, or deal with abstract thinking in the form of formal mathematical reasoning, mathematical modeling, and formal systems of logic. Thus, courses such as MATH 6 (Introduction to Statistics) or BIOL 9,10 (Introduction to Experimental Biology) that deal directly with statistical reasoning would be good candidates for fulfilling this requirement. Courses such as MATH 11 (Calculus A) that expose students to formal mathematical reasoning as well as quantitative applications also would be good candidates. ECON 11 is another course that deals with quantitative reasoning since it features formal graphical modeling as well as analysis of quantitative information. Finally, courses such as PHIL 13 (Introduction to Logic) or PHIL 23 (Symbolic Logic) provide an introduction to formal systems of deductive logic that is another type of quantitative reasoning.

Definition of the Requirement:

The faculty adopted the quantitative reasoning requirement after a report was published by the Curricular Review Committee in 2000. A committee met to come up with the definition and terms of the requirement.

From the *Course of Study*:

The student must earn a minimum of 1/2 Kenyon unit of credit in a course, or courses, designated as meeting the quantitative-reasoning requirement. These courses are marked "QR" in the *Course of Study*. Advanced Placement courses will not satisfy this requirement. Transfer courses that are equivalent to Kenyon QR courses will satisfy the requirement.

Note: A course will satisfy the quantitative reasoning requirement only if it is designated a "QR" course for the semester in which it has been taken. Students should be aware that a particular course may change in character from one year to the next, so that it may count as a "QR" course during one semester but not during another.

Quantitative-reasoning courses may focus on the organization, analysis, and implementation of numerical and graphical data; or they may involve learning mathematical ideas, understanding their application to the world, and employing them to solve problems. In QR courses, students will learn some or all of the following:

- To use statistical methods to analyze and interpret data.
- To make inferences and decisions based on quantitative data—for example, by developing and testing hypotheses.
- To critically assess quantitative information—for example, by reading and critiquing journal articles with quantitative information and analysis.
- To design experiments, and learn and apply data-collection methods—for example, by developing data in laboratory exercises.
- To use mathematical reasoning and the axiomatic method—for example, by using systems of symbolic logic.
- To develop and use mathematical models—for example, to predict the behavior of physical, eco

- nomic, or biological systems.
- To learn and apply the basic ideas of probability, chance, and uncertainty.
- To understand and apply concepts in algorithms and computer programming.
- To communicate quantitative information and mathematical ideas—for example, by construct- ing and interpreting graphical displays.

A given QR course probably will not include all of these abilities, but every QR course will engage students in some of them. In courses identified with the QR tag, the use of quantitative reasoning is a major and continuing theme. Although the subject matter of QR courses will vary by department and discipline, the quantitative knowledge and skills developed will be applicable in a wide variety of settings.

Impact of the Requirement on Enrollments:

Enrollments in introductory-level QR courses were compared for the three years prior to the adoption of the QR requirement (1998-2001) to the three years after the adoption of the requirement (2002-2005). The complete findings are in Appendix A, but are summarized here:

- Across all QR classes examined, total enrollments increased from 1115 per year prior to the requirement, to 1295 after the requirement, a difference of 180 students.
- In the three years after the adoption of the requirement, this is the rank order of total enrollments in introductory QR courses by department: Math, 280; Chemistry, 274; Economics, 244; Physics, 237; Biology, 131; Psychology, 85; Philosophy, 31; and Sociology, 13.
- Across the two time periods, this is the rank order of increase in enrollments by department: Physics, 66 (39 in lecture courses, 27 in lab courses); Psychology, 35 (all related to increases in PSYC 200); Math, 35 (highest increase in statistics of 16); Chemistry, 15 (most increase in lab courses); Sociology, 13 (a QR course was added to the curriculum); Biology, 11 (most increase in lab courses); Philosophy, 8 (all related to increases in PHIL 120); Economics, -2 (increase in 101, but decrease in 102).
- There might be a concern that some classes have grown too large as the result of pressure from the QR requirement. In math we anticipated increased enrollments and we increased staffing, so most average class sizes have not grown larger except for statistics classes where there was an increase of 3 students per course, resulting in an average course size of 22. The increase in enrollment per class was largest in symbolic logic (average increase of 8 resulting in average class size of 31); PSYC 200 (average increase of 5 students, resulting in average class size of 23); chemistry lectures (average increase of 4 resulting in average class size of 34); MATH 106 mentioned above; and ECON 101 (average increase of 2, resulting in average class size of 28).

Survey of Chairs:

Department chairs of departments that teach QR courses were surveyed in the 2004-2005 school year. Their responses are summarized below.

New Courses in the Curriculum:

Have you added new courses to the curriculum (not additional sections of a course), purposely to help students satisfy the QR requirement? If so, please list courses....

CHEM 108: Solar Energy, which will be taught for the first time in the Spring '06 semester. (essentially replacing CHEM 120: Environmental Chemistry, which was not a QR course)

MATH: Math had added two courses to their curriculum prior to the adoption of the QR requirement, which fit the spirit of the requirement: MATH 105: Surprises at Infinity, and MATH 108: Modeling biological growth and form. The department wanted to offer courses to engage students who might not ordinarily take a math course. Since the adoption of the requirement, they taught a biostatistics course one year, but it is not a regular part of the curriculum.

PHYS: Einstein, Phys 104, Fall 2004; Origins, Phys 109, Fall 2003

SOCY376: Research Methods Practicum

If you have added new courses, have the faculty teaching the courses been satisfied with what students are learning in the courses? Are there problems associated with these courses?

MATH: The classes are larger than they normally would be, and there is more student variability, but it is a goal of the math department to teach students who might not normally be interested in taking a math course.

PHYS: In general, I think we've been satisfied with what students are learning in all of our QR courses, including the two mentioned above.

SOCY: We have been satisfied with what students are learning

Increased Enrollments in Existing Courses:

Are there benefits associated with increased enrollments for your department?

BIOL: We have had a slight increase in enrollments, however since the courses that count for QR are lab courses, it takes a certain amount of dedication to the field of biology to use these for the QR requirement. As a department we benefit from this

increase because it demonstrates that many students are interested in biology more generally.

CHEM: We have experienced an increase in CHEM 111, 112 enrollments, but this may or may not be due to QR requirement. We certainly want as many students as we can support taking introductory chemistry!

ECON: We are happy to see increased enrollments in principles and hope that this will translate into a few more majors.

MATH: No particular benefits of increased enrollments except that more students will be exposed to math classes. The requirement does not seem to have increased the number of majors.

PHYS: Yes, in that we enjoy the opportunity to increase the exposure of liberal arts students to physical science and its particular mode of thought – experimental, mathematical, based on a small number of general principles.

SOCY: We are pleased to have students enrolled in our department to complete this requirement rather than having them go to other departments. The course fits our curricular goals.

Are there problems associated with increased enrollments for your department?

BIOL: The increase in enrollments has not been so great as to cause problems.

CHEM: Not enough spots in corresponding lab courses.

MATH: The MATH 106 course, in particular, has experienced a bimodal group of students. There are some students in the course who resent having to take it, and students with a bad attitude can affect the whole class. The department has had to add many sections of this course which means a lot of the teaching time of the statistics faculty is being used to teach introductory courses.

PHYS: The chief problem is that there is more pressure on our labs and lab equipment. Sometimes two (or even three) courses are competing for use of equipment, depending on the lab and demo schedule in each course. We've worked to resolve these issues by checking back and forth when scheduling experiments, and we've also invested some department funds in additional multi-use equipment such as lasers, measuring instruments, etc., where feasible.

PHIL: Our logic classes, which are the only courses we offer that satisfy the QR requirement, have gotten larger and hence more demanding to teach.

PSYC: Yes. Our enrollments in Psyc 200 nearly doubled. This required us to add sections and affected the quality of instruction in the classes. We noticed a bimodal

distribution of performance in the classes that appears to be related to the QR. Enough of the QR –only students performed poorly enough to slow down the entire class (which others in the class complained about). I'm guessing this is due to lack of effort and/or confidence rather than lack of ability.

General, Positive Outcomes of the QR?

From the perspective of your department, have you observed that the QR requirement has led to any beneficial outcomes (for students, faculty, curriculum)? If so, please explain...

BIOL: It has highlighted the quantitative rigor with which the introductory lab course is designed. More generally, we are highly supportive of the QR requirement. It reflects our commitment to instilling both literacy and numeracy in our students. Numeracy is a critical skill to have in dealing with (and making assessments of) the technological advances our society is experiencing.

CHEM: The requirement appears to be meeting the original goal of expecting that a Kenyon graduate can demonstrate competence in basic quantitative reasoning.

ECON: We are glad to see additional students taking economic principles since we think that this will prove useful to them as future citizens whether they take more economics classes or not.

MATH: The math department was happy to see that the faculty supported the adoption of the requirement.

PHYS: Yes, more students are engaging in courses such as Astronomy, Einstein, and Origins, where we put emphasis on how experimental investigations motivate and enhance our understanding of natural science. All students in these courses must participate in active learning opportunities provided by lab exercises

PSYC: I really do think it is good for students to have this information but we have been so overwhelmed by the demand that it has not been at all positive for us.

SOCY: As noted above, this requirement actually fits in with our curricular goals very well. We are trying to encourage sociology students to become more familiar and comfortable with quantitative methods with our practicum course (QR) as well as integrating data into other classes.

General, Negative Outcomes of the QR?

From the perspective of your department, have you observed that the QR requirement led to any negative outcomes (for students, faculty, curriculum)? If so, please explain...

CHEM: None to date. There is optimism that the CPC will maintain a rigorous definition of quantitative reasoning when considering new QR courses.

ECON: There are a few more students in ECON 101 who do not have the analytical ability to do well in the course. They are often frustrated with the course as a result.

MATH: There might be a perception among some students that to satisfy the QR requirement, they need to take a math class (that other courses don't apply). Perhaps we could do a better job of advertising the range of QR courses, and perhaps we could create more courses in various departments throughout the curriculum.

PHYS: There have been negative outcomes for a few students, who have been unwilling or unable to complete the coursework and have dropped one of these courses midway or even later in the semester (in one case leaving a student partnerless for a pair assignment). I'm not sure how much this is tangled up with the institution of the WL option around the same time, but I believe they are related.

PSYC: As I noted, we have been overwhelmed by the demand. Indeed, we are dropping the QR from Psyc 200. We cannot meet the demand.

SOCY: None that we've seen. If students don't want to take the practicum there are several other classes they can take. We encourage our majors who might be headed to grad school to also take the psychology stats course. It would be helpful if they would continue to offer it as a QR for our students (I understand they are dropping it as a QR).

Do you have suggestions for solutions for dealing with the negative outcomes?

CHEM: The new Math Center should be a great college-wide resource for assisting students in QR courses.

ECON: Since the principles sequence is the gateway to all the upper level courses in economics, we are not willing to make the course less demanding as this would do a disservice to our curriculum. We think that the principles sequence is at the appropriate level for the quality of students that Kenyon attracts.

PHYS: We've worked hard to avoid pair assignments (going with individual assignments in some cases and group of three assignments in others). I've (Turner) also taken the position that I will be liberal about agreeing to Pass/D/Fail grading in the astronomy courses I teach, so that students will feel their risk in attempting and staying in these courses is limited and manageable.

PSYC: The only thing that would help is to have more staff to teach Psyc 200 so that we could keep enrollments below 15 in each section without reducing our other course offerings. We routinely have 30-40 majors/year so we should be able to offer 2-3 sections annually to meet the demand. With the QR, even 4 sections are barely adequate.

Any Other Comments on the QR Requirement?

MATH: We should list the group of QR courses in the faculty advisor notebook, and in the Course of Study so that students can see the range of QR courses offered.

PHIL: Generally speaking we think that the QR requirement is a good thing.

PHYS: I believe it's a modest requirement, well worth the time it takes in a student's schedule. It puts some students outside of their comfort zone in a healthy way, encouraging them to grow and gain confidence in a sometimes unused aspect of their intellectual skills.

SOCY: Most of us in the department think it is a good idea. It would be great to have more courses designed for non-majors such as the Einstein course in physics (I think that's the right department) or the medical stats class offered one semester in math.

Appendix A.

**ENROLLMENT DATA FOR QR COURSES -
AVERAGES 3 YRS PRIOR VS. 3 YRS AFTER**

		YEARS:		
BIOLOGY		98-01	02-05	diff
BIOL 109	enroll	72.00	76.33	4.33
LAB CLASS	#crs	5.33	6.00	0.67
	percrcs	13.50	11.67	-1.83
BIOL 110	enroll	48.00	55.00	7.00
LAB CLASS	#crs	4.00	4.33	0.33
	percrcs	12.00	12.69	0.69
<i>total</i>	<i>enroll</i>	<i>120.00</i>	<i>131.33</i>	<i>11.33</i>
	<i>#crs</i>	<i>9.33</i>	<i>10.33</i>	<i>1.00</i>

		YEARS:		
CHEMISTRY		98-01	02-05	diff
CHEM 100	enroll	141.00	147.00	6.00
LECT CRS	#crs	5.00	4.33	-0.67
	percrcs	29.50	33.75	4.25
CHEM 100	enroll	118.67	127.33	8.67
LAB CRS	#crs	8.67	9.00	0.33
	percrcs	13.66	14.04	0.38
<i>total</i>	<i>enroll</i>	<i>259.67</i>	<i>274.33</i>	<i>14.67</i>
	<i>#crs</i>	<i>13.67</i>	<i>13.33</i>	<i>-0.33</i>

		YEARS:		
ECONOMICS		98-01	02-05	diff
ECON 101	enroll	154.33	160.00	5.67
	#crs	6.00	5.67	-0.33
	percrcs	25.72	28.04	2.32
ECON 102	enroll	92.33	84.33	-8.00
	#crs	4.67	4.33	-0.33
	percrcs	19.77	19.45	-0.32
<i>total</i>	<i>enroll</i>	<i>246.67</i>	<i>244.33</i>	<i>-2.33</i>
	<i>#crs</i>	<i>10.67</i>	<i>10.00</i>	<i>-0.67</i>

		YEARS:		
PHILOSOPHY		98-01	02-05	diff
PHIL 120	enroll	23.00	30.67	7.67
SYMB LOG	#crs	1.00	1.00	0.00
	percrcs	23.00	30.67	7.67

		YEARS:		
PHYSICS		98-01	02-05	diff
PHYS 100	enroll	83.00	122.33	39.33
LECT CRS	#crs	2.00	3.00	1.00
	percrcs	41.50	41.00	-0.50
PHYS 100	enroll	88.00	114.67	26.67
LAB CRS	#crs	8.00	8.33	0.33
	percrcs	14.75	13.99	-0.76
<i>total</i>	<i>enroll</i>	<i>171.00</i>	<i>237.00</i>	<i>66.00</i>
	<i>#crs</i>	<i>10.00</i>	<i>11.33</i>	<i>1.33</i>

		YEARS:		
MATH		98-01	02-05	diff
STATISTICS	enroll	77.33	93.33	16.00
(MATH 106)	#crs	4.00	4.33	0.33
	percrcs	19.33	21.85	2.52
NONMAJOR	enroll	27.00	31.67	4.67
(101-110)	#crs	1.33	2.00	0.67
	percrcs	20.33	15.11	-5.22
CALC A	enroll	68.67	64.33	-4.33
(MATH 111)	#crs	4.00	3.67	-0.33
	percrcs	17.17	17.81	0.64
CALC B	enroll	47.67	57.33	9.67
(MATH 112)	#crs	3.67	4.00	0.33
	percrcs	13.11	14.33	1.22
COMP SCI	enroll	24.33	33.33	9.00
(MATH 118)	#crs	1.33	2.00	0.67
	percrcs	18.25	16.67	-1.58
<i>total</i>	<i>enroll</i>	<i>245.00</i>	<i>280.00</i>	<i>35.00</i>
	<i>#crs</i>	<i>14.33</i>	<i>16.00</i>	<i>1.67</i>

		YEARS:		
PSYCHOLOGY		98-01	02-05	diff
PSYC 200	enroll	49.33	84.67	35.33
STAT ANAL	#crs	2.67	3.67	1.00
	percrcs	18.67	23.28	4.61

		YEARS:		
SOCIOLOGY		98-01	02-05	diff
SOCY 297	enroll	0.00	13.00	13.00
METHODS	#crs	0.00	1.00	1.00
	percrcs	0.00	13.00	13.00

ACROSS ALL:		98-01	02-05	diff
	enroll	1115	1295	180
	#crs	62	67	5

key: enroll = total enrollment
#crs = number of courses
percrcs = students per course

