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Quantitative Literacy Task Force
Final Report and Recommendations

Prepared by:
Douglas W. Estry and Joan Ferrini-Mundy

Task Force Members:
George Allen (NUR), Melissa Baumann (EGR), Charles Ballard (EC/SSC), Samuel Drake (UUD), Ross Emmett (JMC), Richard Enbody (EGR), Dennis Gilliland (STT), Kay Gross (KBS), Jonathan Hall (MTH), Nicole Johnson (GA), Karen King (MTH), Andy McCoy (UN), Matthew McKeon (PHL/A&L), Kathy Petroni (ACC/BUS), Victor Piercey (GR), Mark Reckase (TE/CE), Donnie Reinhard (EGR), Robert Tempelman (ANS/ANR), Connie Tingson (GR), Cliff Weil (MTH)

Consultant to the Committee
John Beck
Labor and Industrial Relations

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Preamble

Michigan State University's current quantitative expectations were last reviewed in 1987 as part of a University-wide process that resulted in the Committee to Review Undergraduate Education (CRUE) report. In the spring of 2004 the Provost charged an interdisciplinary team of faculty to reconsider the quantitative literacy (QL) requirements for all MSU students. The Provost proposed that, through a university-wide consensus process, the task force should accomplish the following:

- Establish a dynamic and adaptable vision that describes MSU's QL goal, together with a set of guidelines, expectations, or standards characterizing the intended QL exit requirements of all students who graduate from MSU with a bachelor's degree.
- Develop an assessment plan that is sufficiently adaptable to meet the needs of the diverse academic missions and requirements of the various undergraduate majors at MSU and provides evidence of the degree to which students have met the QL exit requirements.
- Develop a model(s) for an interdisciplinary "University Curriculum" that addresses the QL standards and can be tailored to meet the needs of students with diverse academic interests and backgrounds.
- Recommend a University structure that will allow for appropriate oversight and ongoing evaluation.

That Task Force was charged to complete its work by the end of Fall semester, 2004.

Here we describe the general nature of the problem with QL nationally and at MSU, the deliberation process of the Task Force, the standards and curricular model that the Task Force recommends, an explanation of how the newly designed QL foundation standards might be incorporated into the current mathematics exit requirement to become the QL foundation requirement, and finally, challenges surrounding assessment and implementation.

The Problem: Inadequate Quantitative Literacy

In an increasingly complex world, adults are challenged to apply sophisticated quantitative knowledge and reasoning in their professional and personal lives. The technological demands of the workplace, the abundance of data in the political and public policy context, and the array of information involved in making personal and family decisions of all types necessitate an unprecedented facility not only with fundamental mathematical, statistical, and computing ideas and processes, but with higher-order abilities to apply and integrate those ideas and processes in a range of areas. Universities have essential responsibility in preparing students in this area, given the bleakness of the national picture. Findings from the National Adult Literacy Survey in 1992 indicate that nearly 50% of U.S. adults were at most able to "locate information in text, to make low-level inferences using printed materials, and to integrate easily identifiable pieces of information. …perform quantitative tasks that involve a single operation where the numbers are either stated or can be easily found in text."[1] Analyses of state assessments in mathematics at the end of high school show that the average high school graduate has roughly the equivalent of eighth grade mathematical knowledge (Achieve, 2004).[2]

The recently released results of the Program for International Student Assessment (PISA) in mathematics literacy corroborate the severity of this situation.[3] The performance of U.S. 15 year olds in mathematical literacy and problem solving was lower than the average performance of students in most of the Organization for Economic Cooperation and Development countries. The items used in PISA are intended to measure the application of knowledge to problems within a real-life context. U.S. high schools clearly are not preparing students, and neither are universities. This means that, overall, the U.S. educational system is failing its constituency. If Michigan State University can conceptualize, design, implement, and assess a forward-looking and effective QL program, we will provide a model of how higher education can address a major educational problem for the nation.

Quantitative Performance at MSU

Using mathematics performance as an imperfect proxy for QL, there are indications, based primarily on placement test performance and some analysis of course taking patterns, that MSU students enter the university unable to perform at high levels on the Mathematics Placement Exam (http://www.math.msu.edu/mps/ and Table 1, below) and approximately 40-50% of entering freshmen take remedial mathematics courses. In the 2004-05 year, of more than 7300

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[1] U.S. Department of Education. National Center for Education Statistics. *Technical Report and Data File User's Manual For the 1992 National Adult Literacy Survey*, NCES 2001–457, by Irwin Kirsch, Kentaro Yamamoto, Norma Norris, Donald Rock, Ann Jungeblut, Patricia O'Reilly, Martha Berlin, Leyla Mohadjer, Joseph Waksberg, Huseyin Goksel, John Burke, Susan Rieger, James Green, Merle Klein, Anne Campbell, Lynn Jenkins, Andrew Kolstad, Peter Mosenthal, and Stéphane Baldi. Project Officer: Andrew Kolstad. Washington DC: 2001.

[2] Achieve Inc. (2004). *Do graduation tests measure up? A closer look at state high school exit exams.* Washington, DC:.

[3] Lemke, M., Sen, A., Pahlke, E., Partelow, L., Miller, D., Williams, T., Kastberg, D., & Jocelyn, L. (2004). *International outcomes of learning in mathematics literacy and problem solving: PISA 2003 results from the U.S. perspective* (NCES 2005-003). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

entering freshmen, approximately 1000 were placed in the equivalent of a basic first year high school algebra course (MTH 1825), and 1800 into a college algebra course (MTH 103)—courses that are well below the beginnings of university study of mathematics or a foundation for QL.

Table 1. Number of entering freshman and freshman mathematics enrollment patterns based on performance on the mathematics placement examination.

		Mathematics Course*						
Term	# Entering Freshmen	1825	103	106/112	110	116	124	132
FS97	6,176	1,694(27)	1,745(28)		183(3)	1,058(17)	651(11)	813(13)
FS98	6,419	1,419(22)	1,719(27)		195(3)	871(14)	754(12)	952(15)
FS99	6,088	1,306(21)	1,736(29)	111(2)	173(3)	757(12)	759(12)	793(13)
FS00	6,297	1,172(19)	1,841(29)	107(2)	222(4)	758(12)	78712)	926(15)
FS01	6,324	1,100(17)	1,684(27)	122(2)	388(6)	819(13)	816(13)	848(13)
FS02	6,833	966(14)	1,727(25)	165(2)	429(6)	769(11)	772(11)	766(11)
FS03	6,943	916(13)	1,657(24)	111(2)	461(7)	819(12)	829(12)	728(10)
FS04	7,312	1,046(14)	1,884(26)	101(1)	432(6)	742(10)	983(13)	764(10)

*MTH 1825 Intermediate Algebra, MTH 103 College Algebra, MTH 112 Finite Mathematics: Applications of College Algebra, MTH 110 Finite Mathematics and Elements of College Algebra, MTH 116 College Algebra and Trigonometry, MTH 124 Survey of Calculus I, MTH 132 Calculus I. Numbers in () represent percentage of entering freshman.

Although there has been a decrease in the percentage of students enrolled in the courses considered below the beginnings of university study of mathematics (MTH 1825, 103, 112, and 110), the percentage still remains unacceptably high (47.4%). Interestingly, comparing the three years beginning with FS99 (FS99, 00, and 01) with the most recent three years (FS02, 03, and 04) the percentage of entering freshman enrolling in mathematics courses at the level of MTH 132 or below has gone from an average of 92% to 81%. The decline in MTH 1825 enrollment accounts for approximately half of this decrease. With the exception of MTH 110, which has seen an approximate 2% increase during the same two time periods, all other mathematics courses at the level of 132 and below also have experienced a decrease in the percent of entering freshman enrolling during Fall semester. A variety of variables could account for this: 1) increasing numbers of freshman fulfilling the current mathematics exit requirement through advanced placement, proctored mathematics placement examination, or SAT/ACT scores; 2) increasing numbers of entering freshman placing into mathematics courses above the level of 132; or 3) changes in advising patterns that defer mathematics courses to some time other than the first semester of the student's freshman year.

MSU recognizes the importance of a diverse set of personal and academic characteristics that, when combined, predict success. Currently, MSU strongly recommends at least three years of college preparatory mathematics. Admissions records suggest that approximately 80% of entering freshman students have studied mathematics in high school for four years. Currently, Michigan is one of 5 states that leaves decisions on the specifics of high school mathematics requirements to the local districts. However, there is such diversity and variance in offerings at the high school level[4] that even with four years of study it is difficult to assume that students have had access to any common core of mathematical content, except possibly at the most basic levels of algebra.

MSU currently signals its expectations about the mathematical background viewed as necessary through a mathematics exit requirement, originally outlined in the 1987 CRUE report. CRUE recommended:

> *That all graduates of Michigan State University be required to provide evidence of knowledge in mathematics at a level equivalent to four years of college preparatory mathematics at the high school level.*

Currently, students can complete the MSU mathematics requirement by fulfilling a. or b. below.

a. Waiver through a proctored placement examination yielding a score which would result in placement in Mathematics 132 (calculus).

19+ on the Mathematics Placement Examination or
28 on ACT Mathematics or
640 on SAT Mathematics

b. Completion at MSU or transfer equivalent of either:

(1) One of the following courses:
   a. MTH 106, 110, 116, 124, 132, 152H, 201 or
   b. STT 200, 201

   The completion of MTH 103 and one of the courses referenced in item (1) may satisfy the university mathematics requirements.

or

(2) Mathematics 103 and 114 (equivalent to MTH 116)

Appendix 1 is list of the current **mathematics and statistics** exit requirements for the various MSU college and departments/programs.

How Quantitative Literacy is Organized Elsewhere

The definition, purpose, and existence of QL requirements vary across the Committee on Institutional Cooperation (CIC) institutions as well as other institutions of higher learning across the nation. Whether labeled quantitative literacy, mathematical thinking, quantitative reasoning, quantification, or simply mathematical sciences, quantitative skills are an important aspect of many university-wide liberal or general education programs at eight of the twelve CIC institutions. Ability to evaluate arguments, make informed decisions, analyze and solve problems, gain an appreciation for real-world mathematical applications, and develop formal reasoning skills are common themes among the purposes of QL at the CIC institutions that have

[4] Recent research by Schmidt et al. (2004), involving analysis of transcripts of secondary school students from a large school district, indicates that there are more than 200 distinct pathways through the many course offerings in mathematics (Personal Communication).

such programs. Although all CIC institutions with such programs allow these QL requirements to be satisfied by courses in traditional calculus, additional options include mathematics at or above the level of college algebra, descriptive and inferential statistics, and computer science. Four of the eight CIC institutions allow the QL requirement to be met in part or in whole with courses in philosophy, logic, and reasoning, outside the domain of mathematics. Despite the literature and ongoing national conversation around the need for QL, currently four of the CIC institutions lack a university-wide QL requirement, allowing colleges and/or departments within the institution to develop mathematics requirements.

Other institutions have chosen to meet QL requirements through interdisciplinary courses such as those developed for the NSF-funded Mathematics Across The Curriculum (http://www.math.dartmouty.edu/~matc/) project at Dartmouth College. These courses infuse the use of mathematics in multiple disciplines (see Appendix 2 for examples).

In our review of QL programs at other institutions, we found no significant examples of the following features, which grew to be central in the thinking of this Task Force:

- explicit expectation for building/integrating QL skills throughout a student's undergraduate career.
- setting interim deadlines prior to graduation for meeting the QL requirements.
- explicit expectation that the knowledge acquired in early QL courses be used in other courses in the curriculum.
- establishing a set of standards against which learning outcomes could be measured.
- using assessment as a means of evaluating student learning and the impact of integrated QL experiences so as to drive course/curricular change in a systematic way.

Task Force Process

Throughout the summer and fall of 2004, the work of the Task Force comprised three open forums, six meetings of the full Task Force, a two-day retreat, a meeting with the Council of Deans, a colloquia with advisors, individual meetings with the Director of The Resource Center for Persons with Disabilities and a representative of the Computer Science and Engineering faculty, a meeting with the Academic Council, numerous subcommittee meetings, and individual meetings with college and program administrators across campus.

The committee began its work by articulating a series of expectations and suppositions that would help guide and focus discussions. Several expectations are worth highlighting. First, it was clear that members wanted to create something that was not simply a list of more courses that students would be required to take. They focused on an academic experience that could be integrated into a student's curriculum irrespective of major. Second, they agreed that it would be necessary to "think outside the box," resisting keeping the current course structure in place unless it could be clearly linked to expected outcomes. Third, they wanted to stay focused on the best interests of students and, if at all possible, avoid "turf battles." Fourth, they felt it was important for the institution to articulate clear expectations for the level of student preparation prior to coming to MSU. Finally, it was important that a university-level education be seen as adding depth and breadth to the knowledge and skills that students bring with them.

In part, these expectations were articulated in a series of suppositions that formed the basis for a common ground of understanding among members of the Task Force. These included:

1. Mathematics and QL are different but closely related competencies.
2. The QL of students is a collective, campus-wide issue and responsibility.
3. There must be demonstrated value-added that comes from a post-secondary QL experience.
4. ALL students who graduate from MSU should demonstrate QL.
5. Curricular and programmatic options should be developed that assist students with understanding the current and future relevance of quantitative skills and therefore the importance of life-long learning.
6. It cannot be assumed that high school preparation for college-level QL is adequate.
7. The development of a student's quantitative knowledge and skills is not the exclusive responsibility of any one department.
8. QL should be available in multiple contexts and experiences.

From these suppositions a series of goals were articulated:

- to deepen for all students an understanding of QL that flows from a fundamental understanding and appreciation for the beauty and utility of mathematics and statistics;
- to "raise the bar" as to MSU's quantitative expectations of graduating students;
- to engage the entire university in ongoing discussion, implementation, and review of a definition of QL and what we value in a quantitatively literate MSU student;

- to drive curricular change toward a forward-looking and adaptable vision of QL for all students; and
- to be recognized as effective innovators in QL at the undergraduate level.

Central to the work of the Task Force was coming to consensus around an MSU definition of QL and an associated set of standards that would reflect the quantitative knowledge and skills expected of a graduate. Importantly, the Task Force envisioned these standards as the foundation for the design and implementation of courses and assessment tools. To guide their work, the Task Force used a variety of external resources (see Appendix 3).

As a starting point for a discussion of standards, and on the basis of the Task Force's collective knowledge and experience and a review of the literature (see Appendix 4), seven domains of quantitative knowledge were identified: 1) mathematical and statistical foundations, 2) quantitative reasoning in context, 3) analytical reasoning, 4) applications and problem solving, 5) representation, 6) gathering and using evidence, and 7) modeling. In order to attain some common understanding of these domains, the Task Force identified inputs—major underpinnings, such as courses and co-curricular activities, that would lead to gaining the competency—and outputs—those things that would flow or result from having achieved the competency. The purpose of this exercise was primarily two-fold. First, we needed to determine the degree to which these seven domains reflected the most concise representation of QL knowledge and skills. This work led to a significant consolidation and restructuring of the various domains of knowledge, which we have come to refer to as the MSU **QL Standards**. Second, it was necessary to solidify thinking around a definition of QL. Importantly, the information gathered as a result of exploring the questions of inputs and outputs could serve to guide programmatic reviews of existing courses, particularly as units consider appropriate outcome (output) assessment measures.

Using the definition and the standards as a guide, the Task Force explored curricular models that would facilitate development of the knowledge and skills defined as constituting MSU's vision of QL. There was recognition of the need for a strong computational foundation that would be integrated into disciplinary QL requirements. Initially, the Task Force envisioned a set of pre-requisite knowledge that would serve as the foundation for a two-tiered system that required an increasingly more complex treatment of quantitative skills at each tier. Courses in each tier were to build on and utilize the knowledge gained in the foundation. The foundation was consistently thought of as spanning the domains of mathematics, statistics and computer science and the application components as lying within the various disciplines. There was considerable discussion about the tiered nature of this model and what might constitute the transitional or middle component as students moved from the foundation to the more advanced treatment and application of quantitative skills in the major. Extensive discussions among members of subcommittees charged with identifying issues of implementation and delineating the standards led to the final curricular model presented in this report.

Quantitative Literacy Definition and Standards

Definition

The Task Force reviewed a number of key documents that address the definition of QL and/or provide details about what might be included within the domain of QL. (See Appendix 2 for a list of resources consulted.) Ultimately the Task Force arrived at its own definition and elaboration of QL:

> ***Definition: Quantitative literacy is the ability to formulate, evaluate, and communicate conclusions and inferences from quantitative information.***
>
> **Quantitative literacy employs analytical arguments and reasoning built upon fundamental concepts and skills of mathematics, statistics, and computing. Quantitatively literate MSU students will be more empowered members of a global society through their ability to represent and critique their world.**

The Task Force developed a set of standards for student performance at three different stages in the development of their QL (Prerequisite Knowledge, QL Foundation, and Applied QL). These expectations reflect our view that university-level experiences in QL should add value beyond what is typically expected on completion of high school and that, in part, the value comes from a commitment to an integrated approach to QL.

Standards

1. Prerequisite Knowledge

Ideally, students admitted to MSU should have taken **four years** of mathematics in high school. We recognize that high school mathematics programs will vary widely, and most should far exceed what follows as prerequisite knowledge. MSU's QL program assumes the following basic background **prior to entry** to MSU:

a. procedural fluency (efficiency and accuracy) in arithmetic, including knowledge of ratios, decimals, percents, and basic operations.

b. knowledge of basic algebraic operations, including understanding of commutative, associative, and distributive laws; procedural fluency, including the ability to simplify expressions and solve equations; knowledge of linear functions.

c. knowledge of basic geometric ideas, including properties of two- and three-dimensional shapes, and measurement formulas for area, volume, and perimeter.

d. knowledge of basic statistical ideas, including mean and standard deviation, median and range, and mode, and such graphical representations as bar graphs and pie charts.

e. knowledge of elementary computer and internet usage.

2. Quantitative Literacy Foundation

All MSU students must fulfill the QL Foundation **prior** to admission to junior standing. This includes proficiency in the following areas:

a. knowledge of basic concepts and procedures of algebra and finite mathematics, including solving first and second degree equations, inequalities, and systems of equations and inequalities; understanding of elementary functions (polynomial, logarithmic, exponential, and trigonometric functions), including basic properties, definitions, and graphs; maxima and minima of polynomials; slopes and variable rates of change; orders of magnitude; growth and decay; relationships among types of functions; permutations and combinations; symmetry, similarity, and congruence; relationships among measurements (area, perimeter, and volume).

b. knowledge of basic concepts and procedures of computing, including the concept of algorithms; spreadsheets, databases, and queries; representations of data; constructing and reading basic charts, tables, and graphs.

c. knowledge of basic concepts and procedures in statistics, such as measures of central tendency, measures of variation, percentiles, standard error, statistical significance, and correlation; the difference between correlation and causality; basic ideas of inferential statistics; basic probability concepts; fundamental representations of data, such as box plots, line graphs, and histograms.

d. introductory proficiency in analytical arguments and reasoning, including presenting solutions to problems with appropriate justification, and elementary proof and formal arguments.

3. Applied Quantitative Literacy

All students must complete a set of courses, including at least one in the college, department, or unit in which their major is housed, that address the following proficiencies. A significant portion of the following should be integrated coherently into a meaningful context of application, to show the role of QL in societal decisions, public policy, or problem solving.

a. proficiency in analytical arguments and reasoning, including:

i. crafting quantitative arguments that acknowledge the advantages and limitations of data gathering and analysis~~,~~ and that use logical argumentation, including deductive and inductive reasoning and other mathematical arguments, and

ii. evaluating quantitative arguments with educated skepticism, including recognizing sources of error, ill-specified or incorrect data, and the limitations of quantitative arguments; analyzing mathematical arguments for truth or falsity, deciding when a conclusion is warranted, and recognizing limitations in arguments.

b. proficiency in representing and critiquing the world, including:

i. creating mathematical models and knowing standard mathematical models; translating real-world problems to mathematical representations; abstracting from context; finding underlying structures and patterns; understanding how to use technology appropriately in creating models, and

ii. using mathematical models and representations; assessing the validity of different models for the same phenomenon; predicting and providing information based on a mathematical model; translating and transitioning among representations, including graphs, words, equations, and charts; comparing the utility and interpreting the meaning of different representations; recognizing common errors that produce misleading representations.

c. proficiency in data-based problem solving, including:

i. identifying problems, posing questions, deciding what data are to be gathered; recognizing potential sources of bias in measurement; knowing and designing basic data-gathering processes (e.g., surveys and questionnaires); understanding the role of data in establishing causality, and

ii. implementing data-gathering processes; analyzing and interpreting data using appropriate technologies to solve quantitative problems; making inferences and decisions based on quantitative and qualitative data; understanding basic methods of data analysis; making judgments and predictions based on data; recognizing when aggregation and disaggregation are appropriate and useful; finding and retrieving quantitative information and data.

Quantitative Literacy Curricular Model

This curricular model flows from the above standards and represents a way of enacting them in the context of a university curriculum. The model has two important components. First, the QL Foundation recognizes that achieving a post-secondary level of QL requires a strong foundation in mathematics, statistics, and the use of technology. Second, Applied QL is designed to address the importance of providing a contextual basis for the application of quantitative skills across the curriculum. The following represents the Task Force recommendation for a curricular model.

The Task Force recommends the following curricular model:

QL Foundation

Prior to admission to junior standing, all students must complete the course(s) defined to constitute the QL Foundation. The Task Force envisions the QL Foundation as a reconfiguration of the current mathematics exit requirement which, based on CRUE, is defined as the equivalent of four years of high school mathematics. The Foundation will be offered through a very small number of courses, and the main responsibility for its development will rest with the Departments of Mathematics, Statistics, and Computer Science and Engineering. The development group will seek broad consultation across the university. The Task Force recommends that the following factors be taken into consideration in designing the foundation:

a. Existing courses that fulfill the current mathematics exit requirement should be carefully reviewed in light of the QL standards and, where necessary, either modified or a new course(s) developed to address the knowledge and skills defined by the QL Foundation standards.
b. Consideration should be given to integrating statistical, mathematical, and computational competencies in these course(s).
c. In keeping with the current mathematics course model, the QL Foundation should consist of no more than the equivalent of two university level courses.
d. Consideration should be given to either augmenting or rewriting the mathematics placement examination to address the QL Foundation standards.
e. The Task Force envisions the QL Foundation to be a limited set of courses designed, developed, and overseen as outlined in the section on implementation.
f. As is the case now, students should be allowed to waive this requirement by examination (see Implementation, below).

Applied QL: Discipline Based Distribution Requirement

All majors should require a minimum of two additional courses (or the equivalent) that cover competencies defined by the QL standards. At least one of these courses must be based in the department/program (or college if non-departmentally organized) in which the major is housed. Some units may decide on two distinct courses, while others may demonstrate how the standards are embedded in courses throughout the major. No matter how the applied QL curriculum is arranged, it should be constructed so that students have a coherent experience relevant to the disciplinary applications. Recommended guidelines include:

a. Courses can either be existing or new courses; in either case proposers must demonstrate how the courses address the QL standards.
b. All courses defined as fulfilling QL standards should, at a minimum, have a prerequisite of the QL Foundation, and proposers must demonstrate how this prerequisite knowledge is utilized and/or further developed. Additional prerequisites may exist as appropriate.
c. Programs should have the option of allowing students to fulfill one of the requirements through a course outside of the major. In any case, all courses must be approved as addressing the QL requirement (see Implementation, below).
d. Units needing assistance in modifying or developing discipline based course(s) should consider consultation with faculty from such departments as mathematics, statistics, computer science, or economics.

Assessment

All units must provide a detailed description of an assessment plan for monitoring learning outcomes defined in the standards (see Implementation, below).

General Comments

The QL standards play a central role in the design of new courses or modification of existing courses that will be used to fulfill the requirements outlined by the model. The standards are viewed by the Task Force as dynamic and evolving, based on a growing understanding of QL that will be gained through curricular implementation and assessment.

Based on a clearly delineated set of standards that have evolved through a process of assessment and the accumulation of research-based evidence, it should be possible, in the future, to move to an outcomes-based model for the development of QL knowledge and skills. However, the Task Force was in agreement that our research-based knowledge of what constitutes a university-level understanding of QL is currently too limited to propose this model. It is our hope that through the implementation of assessment studies, it will be possible, over the next three to five years, to implement an outcomes-based approach to the University QL requirements. In addition, as MSU initiatives like Carnegie Teachers for a New Era and the NSF Mathematics and Science Partnership (PROM/SE) continue, and stronger statements regarding pre-college mathematics expectations begin to have an effect on the background of incoming students, it is anticipated that the need will wane for basic (high school level) mathematics courses at Michigan State University. This change will depend in part on MSU providing ongoing and enhanced outreach and professional development support to schools, teachers, administrators and policy makers throughout the state in the area of mathematics.

Issues of Implementation

The Task Force considered a variety of challenges that could impact the overall implementation of the proposed model for QL. In some cases, the Task Force provides recommendations that would address the identified challenge.

Faculty Development and Support

Essential to the success of any programmatic initiative is the ability to change existing culture and embedded expectations. Therefore an important theme in implementation relates to a clear articulation among current faculty, academic staff, and new hires that students' quantitative knowledge and skills are the responsibility of all faculty, not just those in the more traditional quantitatively intense disciplines.

This broad responsibility presents an interesting set of related but different problems. For faculty who already provide quantitative courses it may require a re-evaluation of how concepts in QL differ from or augment the current mathematical and statistical graduation exit requirements. For others who are less comfortable with the implementation of quantitative components into discipline-based courses, this will require enhanced opportunities for collaboration with faculty in the quantitative disciplines and/or enhanced professional development opportunities. Resources may also need to be made available to faculty for graduate assistant support in the development of QL courses and to locate curricular materials and assessment tools.

The Task Force recommends that the Office of Faculty and Organizational Development along with the Graduate School and the Teaching Assistant Program implement a series of ongoing professional development activities designed to assist faculty and graduate students in the development of a clearer understanding of what constitutes QL and with the implementation of quantitative skills in discipline-based courses. For graduate assistants these initiatives would dovetail nicely with programs like the Certificates in College Teaching and the developing MSU model for the Center for the Integration of Research Teaching and Learning. We expect that such efforts would call upon the substantial campus expertise in the Departments of Mathematics, Statistics, and Computer Science to support and enhance our collective knowledge of issues of teaching and learning in the quantitative area.

Advising and Progression in the Major

The proposed model requires that students complete the QL foundation prior to admission to junior status. This expectation will place increasing pressure on advisors to ensure that the foundation is complete and, if necessary, remediated early. In addition, there will be increased pressure placed on remedial courses and tutoring programs as students face the reality of completing the foundation in two years. It is anticipated, however, that as reforms in K-12 education begin to result from such national projects as Teachers for a New Era and the Mathematics and Science Partnership there will be increased attention in the K-12 community to mathematical and quantitative skills and reduced demand for QL foundation courses. More students will enter MSU prepared to deal with the quantitative components of courses in the major.

In the short term, these changes will require a series of on-going in-service opportunities for advisors, possibly coordinated through the Advisor In-service committee. In addition, there will be a need for continuing initiatives through such programs as the Office of Supportive Services (Mathematics Enrichment for CAAP students), the Learning Resource Center (tutoring), the Charles Drew Science Enrichment Laboratory (Mathematics Enrichment), the Emerging Scholars Program, and the Mathematics Learning Center.

Course/Curricular Requirements

The Task Force recommends that students be allowed to complete the QL Foundation requirement through an appropriate score on a placement examination. There was strong consensus, however, that the applied QL courses required in the major be integral to developing a more advanced understanding of QL and, therefore, not courses that could be waived. The Task Force felt strongly that majoring in a traditional quantitative discipline that requires significant mathematical and/or statistical knowledge was not, in and of itself, sufficient to insure a student's QL (see Course Load, below).

The above recommendation will require either that the current mathematics placement examination be augmented or that a new placement/diagnostic test be developed that will evaluate the knowledge and skills defined by the QL standards and implemented in the QL Foundation course(s). The latter recommendation is based on the supposition that there must be added learning associated with a college education (new knowledge, skills, and applications that go beyond what is currently expected in the K-12 system) and that this learning take on a component that addresses the portion of the definition dealing with "empowered members of a global society (with the) ability to represent and critique their world."

At least three issues require further consideration.

1) *The role of transfer credits as a way of meeting the various components of the QL requirement*. If curricular requirements evolve as anticipated, it may be difficult to find a one-to-one correspondence with courses taken at other institutions. Transfer students should be able to place out of the QL Foundation based on examination. Further consideration will need to be given to the use of transfer credits as a way of fulfilling discipline-based requirements. This is particularly relevant in programs with articulation agreements for students coming to MSU from community colleges.

2) *The use of standardized test scores to waive the QL foundation*. As is the case with the current mathematics placement examination, the issue here is the degree to which standardized tests (ACT or SAT) measure QL knowledge and skills. As the courses that make up the foundation are modified to align with the competencies and as the placement examination is updated to evaluate those competencies, further analysis of the use of standardized test scores will be necessary.

3) *Initial placement by examination*. With regard to the placement examination, the Task Force recognizes that there will be an important demand, particularly among the quantitative disciplines, to continue an evaluation of a student's mathematical preparation. Since mathematics preparation differs in definition from QL, careful consideration will need to be given to whether the best approach is to develop a new placement examination or to modify/augment the current examination.

Course Load

Throughout its deliberations, the Task Force was very conscious of the need to avoid expanding curricular requirements, particularly in the accredited professional majors. Therefore, beyond the need to incorporate the standards into courses that make up the current mathematics exit requirement (QL Foundation) as well as into existing discipline based courses, the Task Force does not envision the need for any substantial number of new courses. Units will therefore need to review systematically the content of current major courses within the context of the QL standards. Subsequently, each unit will need to submit a proposal indicating how and with which courses they intend to fulfill the requirements defined by the model. Such proposals should outline: a) how the course(s) in the major build on the QL Foundation prerequisites, b) which standards are addressed by the course(s), and c) the assessment plan that will be implemented to evaluate QL learning outcomes relative to the goals detailed in the standards (see Assessment, below).

Assessment

Somewhat unique to the proposed model for QL at MSU is a set of goals coupled with standards that define the knowledge and skills of a quantitatively literate student. The Task Force was faced with the fact that there is no national norm that clearly defines QL. Therefore, the standards represent a dynamic document that will evolve as we gain knowledge and familiarity with this topic. However, this evolution can occur only through a systematic review of evidence. The potential for a unique contribution to a more quantitatively literate global community lies in the set of defining standards. The standards serve as the basis for the focused development of assessment tools. Initially, the Task Force envisions two levels of assessment:

1) assessment embedded in programmatic requirements for QL, and
2) Campus-wide, longitudinal assessments that provide indicators of institutional progress and evidence on which to base changes in the standards.

In the former case the assessments should be used programmatically to evaluate growth and to drive change. These assessments could take the form of written assignments, examinations, portfolios, etc. The key is that they be tied to standards that the unit has defined as being critical to disciplinary course requirements. In the latter case, we envision a larger longitudinal study that looks at a cross section of undergraduates and evaluates their QL skills over time.

The issue of learning outcomes assessment is particularly relevant as we prepare for the spring 2006 accreditation site visit by the North Central Association. Considerable time and effort have gone into establishing a culture of assessment at MSU, but again, this is an area that will require ongoing faculty, academic staff, and graduate assistant development. Therefore, professional development opportunities will continue to be critical. The Task Force recommends that the Office of the Director of Assessment continue to work closely with faculty and graduate students to develop workshops that will enhance awareness of assessment tools and aid unit assessment efforts. In addition, the Task Force has initiated discussions for a campus-wide pilot study of students QL knowledge and skills. This work will be based in the newly developing Center for Statistical Training and Consulting (CSTAT). CSTAT could serve as the focal point for ongoing longitudinal studies. Currently, a pilot study is underway that is designed to establish a benchmark for the current QL abilities of a cross section of students at MSU. In cooperation with CSTAT, an assessment tool is being developed and a study population identified. The intent is to recruit and test students during the Spring semester of 2005.

Attention will need to be paid to a mechanism for periodically accumulating assessment data for the purposes of reviewing the model, improving the standards, and evaluating change across the institution. At a minimum, the mechanism should include the University Assessment Officer, possibly in consultation with the QL subcommittee of UCC (see Oversight and Academic Governance, below).

Oversight and Academic Governance

A recurring theme throughout the Task Force discussions was to avoid what was termed "watering down" of the current quantitative (mathematics exit) requirement. There is no one ideal system that can assure that all programs meet the anticipated high standards envisioned by the Task Force. However, within the confines of the current curricular process appropriate levels of oversight can be established. In combination with appropriate assessment strategies, these can move the institution toward the more rigorous vision of QL defined by the standards.

For oversight of the QL Foundation, the Task Force envisions a committee composed, at a minimum, of faculty from Mathematics, Statistics, and Computer Science and Engineering, and including someone with assessment expertise. In consultation with appropriate campus constituencies, this committee will be charged with the development and oversight of the limited set of course(s) making up the QL Foundation. In addition, their tasks will include assessment and the development and implementation of an augmented or new placement/diagnostic examination that evaluates knowledge and skills defined in the QL standards. This group could also serve as the design team for the development of the desired longitudinal assessment tool.

All new or revised courses, whether part of the QL Foundation or recommended by the units as fulfilling the Applied QL component of the model, will be evaluated through the normal curricular review process. At the university level, however, the Task Force recommends review by a new QL subcommittee of UCC. This subcommittee should have diverse faculty representation and be anchored by members with strong quantitative backgrounds. Initially this subcommittee will need to define the types of questions/criteria that units must address if a course or set of courses is to be approved as fulfilling the QL requirement. At a minimum, this requirement will include demonstration of how course content addresses competencies defined in the standards, how the course uses or builds on QL Foundation material, how the applied QL experience in the major is coherent, and how student learning will be assessed. For some units, this will be a relatively easy process and may require only minor modification of existing courses. For others, particularly units where expertise may not suffice to evaluate and/or implement QL standards, units may need to call on experts to assist in course design. In some cases, the Task Force envisioned units developing or re-designing one course in the major and then requiring a second course outside of the major. In other cases, units may choose to demonstrate how a series of existing courses in the major fulfills competencies defined by the standards.

As previously indicated, the standards serve as a unique set of benchmarks for course design and assessment that will guide the course/curricular review process. Finally, the Task Force envisions that courses approved through this process will be designated as fulfilling the university QL requirement similar to the way that Tier II writing is designated.

Resources

There will be a highly varied need for resources as this new program is implemented. Although not quantified at this point, there will be a need for non-recurring funding, especially in the initial phases of implementation. In particular, these funds will need to be directed toward the development of the QL Foundation, the placement examination, and professional development/faculty support for the design and implementation of Applied QL courses. In addition, consideration will need to be given to supporting periodic longitudinal assessment. The Task Force recommends seeking outside funding to help support the initial phase-in and evaluation of the model.

Communication with Stakeholders

Any implementation plan must take into consideration how MSU will communicate its QL expectations to key stakeholders. At a minimum these encompass public and private K-12 systems and community colleges. The standards articulate mathematical and statistical entrance expectations/requirements that are consistent with four years of high school mathematical preparation. Michigan State University has a long-standing commitment to the land grant philosophy of access to higher education. Even in the face of increasing academic indicators among admitted classes, the Task Force does envision an ongoing need for enrichment programs. However, increasing state and national focus on the nature and quality of K-12 education will continue to alter the demographics of incoming students. As we increase our expectations for entry-level competencies in mathematics, it may be time to revisit what we need to say about MSU's expectations/requirements for mathematics and QL to outside constituents. Consideration will need to be given to the form that the communication takes and any necessary phase-in period, particularly if admission requirements are altered.

Timeline for Implementation

Beyond the necessary and appropriate discussion of the recommendations within academic governance, it will be necessary to develop a timeline over which the various components of a final model will be phased in. Given the connected or spiral-like nature of the recommended model, it will be necessary to begin immediate discussions around the composition of the QL

Foundation course(s). At least initially, in the 2005-06 academic year, the current mathematics exit option will be available to serve as the QL foundation for students. During that year, the QL Foundation committee will meet to examine the set of courses that currently make up the mathematics exit requirement for their alignment with the QL standards. We anticipate that this review will result in some modifications to the courses that currently constitute the mathematics exit requirement and/or the addition of new courses that enable students to meet the Foundation requirements. Changes will also involve either modification of the mathematics placement exam or design of a second exam to assess QL competencies. The form and content of the QL Foundation becomes critical by virtue of defining the knowledge and skills evaluated by the placement examination and because of the pivotal role it plays in providing prerequisite knowledge for the Applied QL courses.

The development of the applied QL component should begin soon after the work on the QL Foundation is underway, so that there can be coordination and integration of the two components. Realistically it may require three to five years to phase in both the QL Foundation and the Applied QL components of the model.

Conclusion

Unquestionably, the national problem of quantitative illiteracy is the collective responsibility of K-12 and higher education. The QL goals that have been outlined here, together with the recommendations for design and implementation, have the potential to make a significant difference in the knowledge and capacity of MSU graduates. The idea of a quantitative foundation that is then applied in meaningful ways within a student's particular interest area is educationally sound and innovative. By implementing and assessing this proposed program, MSU can provide essential leadership that demonstrates how large universities can "scale up" QL in a substantial way. As they prepare to become effective citizens, professionals, and leaders, our students deserve nothing less.

Appendix 1
College and Department/Program Mathematics and Statistics Requirements[5]

College of Agriculture and Natural Resources

College Graduation requirements

- Math 110 or 116. This requirement can be satisfied by placing into calculus based on placement test.

Dept of Ag Econon

- Either STT 200, STT 201, or STT 315.

Dept of Ag Engineering

- MTH 124.
- One of the following courses: STT 200, STT 201, STT 315, or STT 421.

Dept of Animal Science

- MTH 116 (Pre-veterinary Concentration).
- STT 201.

Dept of Community, Agricultural, Recreation and Resource Studies

- None beyond the University requirement if includes STT.

Dept of Crop and Soil Sciences

- University requirement or MTH 116, MTH 132, and STT (the latter are major dependent).

Dept of Entomology

- MTH 124.
- Either MTH 126 or STT 421.

Dept of Fisheries and Wildlife

- MTH 124.

Dept of Food Science & Human Nutrition

- MTH 124, MTH 126.
- Food Biotech, Food Chemistry, Food Packaging, Food Safety, and Food Technology concentrations: STT 201.
- Food Business concentration: STT 315.

Dept of Forestry

- MTH 116.
- Forest Science Option: MTH 124 or MTH 132.
- Wood Products Manufacturing and Marketing: STT 421.

Dept of Horticulture

- University Requirement.
- Horticulture Landscape Design, Construction, Management: MTH 116.

School of Packaging

- Either MTH 124 or MTH 132.
- Either STT 200, STT 201, or STT 315.

Dept of Plant Pathology

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[5] List does not include mathematics or statistics courses that are considered selectives, nor does it include quantitative methods courses that would likely fulfill the new "Applied QL" requirement.

- Either STT 201 or MTH 124.

College of Arts and Letters

- University requirement

Eli Broad College of Business

- For admission: Either MTH 103 or MTH 124
- For graduation: MTH 124 and STT 315

School of Hospitality Business

- MTH 103 and STT 201

College of Communication Arts and Sciences

- University requirements
- Dept of Audiology and Speech Sciences either PSY 295 or STT 200

Dept of Journalism

- Mathematics 5 to 7 credits
  - Mathematics 110 or 116 (5 credits) OR
  - Math 103 AND one of the following: Math 106, Math 114, STT 200 or STT 201

College of Education

- Elementary Ed. MTH 201 and 202
- Secondary Ed, depends on departmental major

College of Engineering

Admission

- MTH 132 and MTH 133

Graduation

- MTH 234, and MTH 235 (Computer Science may take MTH 324 instead of MTH 235)

Applied Engineering

- STT 351

Dept of Biosystems and Agriculture Engineering

- No additional MTH or STT beyond College requirement

Dept of Chemical Engineering and Materials Science

- STT 351 (Chemical Engineering)
- STT 351 (Materials Science and Engineering)

Dept of Civil and Environmental Engineering

- STT 351 (Civil Engineering)
- Environmental Engineering: no additional MTH or STT beyond College requirement

Dept of Computer Science and Engineering

- STT 351 (Computer Science)

Dept of Electrical and Computer Engineering

- Computer Engineering: no additional MTH or STT beyond College requirement
- Electrical Engineering: no additional MTH or STT beyond College requirement

Dept of Mechanical Engineering

- STT 351

College of Human Ecology

Child development

- MTH 201, 202 (TE Program)

Family Community Services

- STT 200 or 201 (can be used to fulfill University requirement)

Family & Consumer Sciences

- STT 200 or 201 (can be used to fulfill University requirement)

Dept of Food Science and Human Nutrition

- Dietetics: MTH 103 or 116 and STT 200 or 201 (May be used to fulfill the University requirements)
- Nutritional Science: MTH 124 or 132 and MTH 126 or 133 or STT 201 or 421

Dept of Human Environment and Design

- Apparel and Textile Design, Interior Design, Merchandise Management: nothing beyond the University requirements.

Food Nutrition

- Either MTH 103 or 116
- Either STT 200 or 201

James Madison College

University requirement with the following exception:
Political Theory and Constitutional Democracy

- One college-level math course selected from: MTH 126, 133, 152H, 153H

College of Natural Science

College requirements for Bachelor of Science or Arts:

- One semester of Calculus
- Second semester of Calculus or one semester of Statistics

Dept of Chemistry

BS Chemistry

- MTH 234, 235

BS Chemical Physics

- MTH 234, 235
- Two of the following: MTH 310, 314, 320, 351, 421, 425, 441, 442, 443, 451

BS Computational Chemistry

- MTH 234, 235, 314, 351

Dept of Geology

Environmental Geosciences or Geological Sciences

- EITHER MTH 234 or one statistics/probability course

Geophysics

- MTH 234, 235

Dept of Physics

BS Physics

- MTH 234, 235, two additional math courses at the 300 level or above

BS Astrophysics

- MTH 234, 235

BA Physics

- MTH 234, 235, one additional math courses at the 300 level or above

BS Physics and Geophysics

- MTH 234, 235

College of Nursing

- STT 200 or STT 201 (Fulfills the University requirement)

College of Social Science

- Completion of the University requirements

Dept of Economics

BA Economics

- Either MTH 124, 132, or 152H
- Either STT 315, 421, 430, or 441

BS Economics

Must choose from the following courses to meet the Natural Science requirement (15 hours)

- MTH 133, 153H, 234, 235, 254H, 255H, 309, 310, 314, 320, 340
- STT 441, 442, 461, 471

Requirements for degree

- Either 132 or 152H
- Either STT 315 or 421 or 430 or 441

Dept of Geography

Landscape Architecture

- MTH 116 (Used to fulfill University requirement)

Urban and Regional Planning

- MTH 103, STT 201 (Used to fulfill University requirements)

Dept of Political Science

BA Political Science

- MTH 103, 110, 116, 124, 132 (Used to fulfill University requirements)

BA Public Administration and Public Policy

- MTH 103, 110, 116, 124, 132 (Used to fulfill University requirements)

Dept of Sociology

- STT 200 or 201 or 421 or 422

College of Veterinary Medicine

Veterinary Technology

- Either MTH 110 or 116 (Used to fulfill University requirements)

Appendix 2
Examples of QL Courses

University of Colorado

”This course was designed to promote mathematical literacy among liberal arts students. This is not a traditional math class, but is designed to stimulate interest in appreciation of mathematics and quantitative reasoning as valuable tools for comprehending the world in which we live. In the course, a student will see basic mathematics, logic, and problem solving in various contexts, such as science, technology, society, and higher level mathematics.”

Dartmouth College

”**Mathematics and Science Fiction** draws on a substantial body of novels and stories that depend on mathematical ideas. Is mathematics simply a way of mystifying, even intimidating readers or does understanding the underlying mathematics contribute to the total experience of reading a story? This course presents both the mathematics and the literary concepts necessary for an informed reading of the texts. Developed and co-taught by a mathematician and a comparative literature professor.”

“Pattern examines the interplay between the art of designing repeat patterns and the mathematics of analyzing those patterns in terms of their symmetries. Through studying and creating works of art – ranging from mandalas to Islamic mosaics to Escher to wallpaper groups – students are introduced to elementary group theory. Developed and co-taught by a mathematician and an artist.”

“Renaissance Math in Fiction and Drama explores how scientific developments in Renaissance astronomy were portrayed in literature and drama past and present. Students use Renaissance technology to track the transit of Mars across the sky. Developed and co-taught by a mathematician and a drama professor.”

Kalamazoo College

“Quantitative Analysis and Statistical Reasoning (is) an introduction to the use of quantitative analysis and statistical reasoning in the fields of sociology, anthropology, and human development and social relations. The course will emphasize understanding and critiquing data and conclusions, and students will produce data sets as well. Students will develop skill in using SPSS.”

“**Quantitative Reasoning and Statistical Analysis** (is) an introduction to some of the quantitative techniques used to clarify ordinary experience and to some of the statistical ideas used to shape public policy and human sciences, with emphasis on the concepts involved in producing, organizing, and drawing conclusions from data.”

Appendix 3
Resources

<u>Definition of Quantitative Literacy</u>

Quantitative Reasoning is the process of forming conclusions, judgments or inferences from quantitative information. There are many aspects to quantitative reasoning. These include the recognition and construction of valid mathematical models that represent quantitative information; the analysis and manipulation of these models; the drawing of conclusions, predictions or inferences on the basis of this analysis; and the assessment of the reasonableness of these conclusions.

University of Wisconsin-Madison

Quantitative reasoning is first and foremost reasoning. It is not mathematical manipulation or computation, but rather the methodology used to analyze quantitative information to make decisions, judgments, and predictions. It involves defining a problem by means of numerical or geometrical representations of real-world phenomena, determining how to solve it, deducing consequences, formulating alternatives, and predicting outcomes.

University of Michigan

1. Interpret mathematical models such as formulas, graphs, tables, and schematics, and draw inferences from them.
2. Represent mathematical information symbolically, visually, numerically, and verbally. Use arithmetical, algebraic, geometric and statistical methods to solve problems.
3. Estimate and check answers to mathematical problems in order to determine reasonableness, identify alternatives, and select optimal results.
4. Recognize that mathematical and statistical methods have limits.

Mathematical Association of America

Elements of QL include:

Confidence with mathematics, cultural appreciation of the nature and history of mathematics, interpreting data, logical thinking, making decisions using mathematics, using mathematical tools in specific settings where the context provides meaning, number sense, practical skills, prerequisite knowledge (algebraic, geometric, and statistical tools), symbol sense.

Mathematics and Democracy: The Case for Quantitative Literacy, editor L.A. Steen

That all graduates of Michigan State University be required to provide evidence of knowledge in mathematics at a level equivalent to four years of college preparatory mathematics at the high school level.

This is defined to include the role of numbers and their impact on human perception; abstract mathematical symbols (algebra); visual aspects of mathematics (graphs; solids, curves and surfaces of geometry). The aim of much mathematical study is the synthesis of ideas with the goal of presenting a simple and cogent account of complicated theories.

The Report of CRUE: Opportunities for Renewal – 1988

Additional Resources

CUPM. (2004). Undergraduate programs and courses in the mathematical science. CUPM curriculum guide 2004. Washington, DC: Mathematical Association of America.

Ganter, S., Barker, W. (Eds.). (2004). Curriculum Foundations Project: Voices of the partner disciplines. Reports from a series of disciplinary workshops organized by the Curriculum Renewal Across the First Two Years (CRAFTY) subcommittee of the Committee for the Undergraduate Program in Mathematics (CUPM). Washington, DC: Mathematical Association of America.

Mathematical Association of America. (1998). Quantitative Reasoning for College Graduates: A Complement to the Standards [Web site]. MAA on line. Retrieved, from the World Wide Web: http://www.maa.org/past/ql/ql_toc.html

Paulos, J.A. (1998). Innumeracy: Mathematical illiteracy and its consequences (1st ed.). New York, NY: Hill and Wang.

Steen, L.A. (ED.). (1990). On the Shoulders of Giants: New Approaches to Numeracy. Washington, D.C.: National Academy Press

Steen, L.A. (Ed.). (1997). Why Numbers Count: Quantitative Literacy for Tomorrow's America. New York: College Entrance Examination Board.

Steen, L.A. (2001). Mathematics and Democracy: The case for quantitative literacy. National Council on Education and the Disciplines and The Woodrow Wilson National Fellowship Foundation.

Ready or Not: Creating a high school diploma that counts. (2002) The American Diploma Project Executive Summary. Achieve, Inc. Washington, D.C. http://www.achieve.org.

Korey, J. (2000). Dartmouth College mathematics across the curriculum evaluation summary: Mathematics and humanities courses.
http://www.math.dartmouth.edu/~matc/Evaluation/humeval.pdf

Bennett, J.O., Briggs, W.L., Morrow, C.A. (Preliminary Edition) Quantitative Reasoning: Mathematics for citizens in the 21 Century. Addison-Wesley Publishing Company.

Jordan, J., Haines, B. (Summer 2003). Fostering Quantitative Literacy: Clarifying goals, assessing student progress. Peer Review, AAC&U.

Appendix 4: Comparison of QL Standards

Steen	Kilpatrick	Conley	Dartmouth*	MSU Open Forum	QL Task Force**
Confidence with Mathematics Number Sense	Productive Disposition-Habitual inclination	Thinking Conceptually Taking Risks (HM) Sustained Inquiry (HM) Modifying, adapting, and combining mathematical tools to find new ways to reach a solution	Taking mathematics seriously	Judging sources and the accuracy of the data they provide (finding and retrieving sources)	Decompartmentalized thinking Power and limitations of Mathematics Arithmetic/numeracy Notion of quantitative methods Confident critical thinking Opportunities & limitations of quantitative analysis
Cultural Appreciation		Experimental Thinking and a willingness to investigate multiple approaches Tolerating Ambiguity on the road to solution (HM)	Comfort using mathematics to facilitate understanding of other subjects and to draw upon other subjects to improve mathematical knowledge		Educated skepticism of quantitative results Mathematics appreciation Appreciate the power and limitations of quantitative reasoning
Interpreting Data	Strategic Competence-Ability		Approach data in a mathematical manner	Interpreting statistical data Understanding probability	Comprehension of methodologies to analyze quantitative information Problem solving/data interpretation Reading and interpreting chars and graphs
Logical Thinking Making Decisions Mathematics in Context	Adaptive Reasoning-Capacity for Logical Thought	Logical Reasoning and Common Sense		Applying Logic and Reasoning, making and judging arguments Using deductive processes	Logic and reasoning Making informed decision Judgments, and predictions Make and determine when a conclusion is warranted Abstract reasoning Logical argumentation
Prerequisite Knowledge	Procedural Fluency-Skill	Ability to use Formulas and Algorithms		Understanding and applying basic concepts	
Practical Skills		Relating abstractions to life outside of mathematics courses		Analyzing and using quantitative tools	(Discussed as a variety of examples) Reading opinion polls, critiquing methodology (sampling and estimation theory) Financial Data
Symbol Sense		Translate real situations into mathematical representation and extract meaning from mathematical expressions Comfort with mathematics terminology Moving from symbolic to verbal representation		Translating among representations Modeling and representing mathematical ideas	Ability to translate between a verbal description and understand what it means quantitatively Represent, symbolically, the methods of analysis used Converting real world problems into abstract mathematical problems Functions as models of the real world
					Spatial relations and reasoning

*Much of this work was stated as goals, e.g.: "Mak(ing) mathematics welcome and even indispensable across the entire curriculum; Broaden(ing) the diversity of those undergraduates enrolling in math or science courses; Stem(ming) the flow away from science and math of students with talent and ability."

**Introducing quantitative concepts into course work across the University was a theme. Additional: Technology: Causality: Recognizing the benefits and drawbacks of various modes of aggregating and describing quantified information.