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Serving Two Masters : A Study of Quantitative Literacy at Small Colleges and Universities

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SERVING TWO MASTERS:

A STUDY OF QUANTITATIVE LITERACY

AT SMALL COLLEGES AND UNIVERSITIES

A DISSERTATION

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We hereby approve the Dissertation

SERVING TWO MASTERS:

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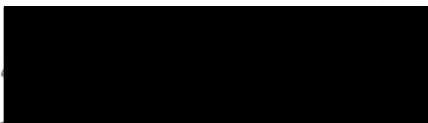Dissertation Committee:

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ABSTRACT

SERVING TWO MASTERS: A STUDY OF QUANTITATIVE LITERACY

AT SMALL COLLEGES AND UNIVERSITIES

by Jodie Ann Miller

The past twenty years have seen a growing interest in promoting quantitative literacy

(QL) courses at the college level. At small institutions, financial realities impose

limitations on faculty size and therefore the variety of courses that may be offered. This

study examined course offerings below calculus at four hundred twenty-eight small

colleges to gain a thorough understanding of the approaches to developing QL among the

general population of undergraduate students. Using a three-phase model of examining

progressively narrower subsets of QL programs at small institutions, document-based

data from college catalogs and communication with mathematics program chairs were

studied to summarize the most common approaches to QL, and to provide narrative

descriptions of courses and programs most consistent with the recommendations of the

Mathematical Association of America. The analysis of the data includes information on

actual curricula and enrollments, and uses qualitative techniques to provide descriptions

of successful courses and programs. Through this analysis, variables important in

developing effective QL courses and programs at the undergraduate level were identified.

The support of both the mathematics department and an institution's administration were

determined to be necessary factors in successful QL programs. Other factors contributing

to program or course success were the individual efforts of faculty members in teaching

QL courses, and the development of print-based materials conducive to effective QL

instruction. Finally, the study provides recommendations for developing resources to support instruction and suggests future research to promote the development of the growing body of knowledge surrounding efforts to teach quantitative reasoning within the general education curriculum.

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List of Abbreviations

AAC&U – American Association of Colleges and Universities

ACTA – American Council of Trustees and Alumni

AFT – American Federation of Teachers

AP – Advanced Placement Program

AMATYC – American Mathematical Association of Two-Year Colleges

CLEP – College-Level Examination Program

CRAFTY – Curriculum Renewal Across the First Two Years

CUPM – Committee on the Undergraduate Program in Mathematics

FTE – Full-time equivalent (in reference to enrollment)

GATC – Geometry, algebra, trigonometry, calculus (in reference to the traditional

mathematics curriculum)

MAA – Mathematical Association of America

MQI – Modeling with Quantitative Information

NCED – National Council on Education and the Disciplines

NCTM – National Council of Teachers of Mathematics

NSF – National Science Foundation

QL – Quantitative literacy

SLO – Student learning outcome

Chapter 1. Introduction

As a new member of the mathematics faculty at a small liberal arts college, I found myself in the middle of an ongoing debate – should the college's quantitative courses below calculus focus on preparing students to take more math courses, or should they concentrate on developing mathematical reasoning skills useful in many disciplines? The facts at my institution were that many students found the standard College Algebra course to have minimal connection to their major field of study, and the course was taught from an algorithmic perspective that did little to excite interest or stimulate mathematical reasoning ability. In spite of this, College Algebra was used by most of the students at the institution to fulfill the core requirement of a "quantitative reasoning" course, and was a prerequisite for all other mathematics and statistics courses. The only students waived from the quantitative reasoning requirement were those entering with CLEP or AP credit for calculus.

These issues led me to reflect upon the trend toward quantitative literacy that has been occurring in collegiate mathematics for the past several decades. Following a few short-lived initiatives in the mid-twentieth century, the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America formed its Subcommittee on Quantitative Literacy Requirements in late 1989 (MAA, 1994). The activities of this subcommittee, coupled with standards for K-12 mathematics education published by the National Council of Teachers of Mathematics (NCTM, 1989 & 2000), drew attention to quantitative literacy as an essential component of mathematics programs at colleges and universities.

Publications over the past twenty years have recommended a variety of approaches to quantitative literacy, and will be reviewed extensively in the next section. However, the realities of course offerings and resource limitations at my current institution have led me to wonder how other small institutions have fared in implementing such recommendations. Therefore, the primary focus of the research was to examine the mathematical core curricular requirements at small colleges and universities.

Research Questions

What approaches are being used to develop quantitative literacy among the general population of undergraduate students at small colleges and universities? Which approaches are consistent with the recommendations of the Mathematical Association of America's Committee on the Undergraduate Program in Mathematics (CUPM, 2004)? What factors contribute to the successful implementation of programs consistent with MAA/CUPM recommendations? How do mathematics departments at small colleges balance the needs of the general population of students along with the needs of students majoring in the mathematical sciences?

At most colleges, there is a common set of course requirements that must be taken before the baccalaureate degree is conferred. Variously called "distribution requirements," "core curriculum," "general education requirements," or by other names, these courses are designed to serve all students at an institution. The quantitative elements in these core curricula were the primary focus of this study.

The title of this work, "Serving Two Masters," refers to the conflicting demands on mathematics faculty to satisfy an institution's need to serve all students by providing courses that fall within the core curriculum, but also to meet the needs of undergraduates majoring in the mathematical sciences. At small institutions like my own, there may be so few full-time mathematics faculty that advanced courses can only be offered on a multi-year rotation. Coupled with a demand for a greater variety of courses to service the general population of students, institutions with limited faculty resources may be faced with difficult choices.

For the purpose of this study, a *small* institution was defined as one for whom the full-time undergraduate population is no more than two thousand students. In recognition of potential conflicting demands on many mathematics departments, this study restricted itself to small institutions that also offer an undergraduate major in mathematics or applied mathematics. Although many of these institutions may also offer a program of study in mathematics education, a number of factors including degree names, minors, and state certification requirements complicate the identification of colleges and universities offering mathematics education programs at the middle and secondary levels.

This study took a qualitative approach to developing a comprehensive view of core curriculum requirements in the 2010-11 academic year at all of the colleges in the population. Following initial data gathering from publicly available sources, the researcher attempted to clarify questions raised by the initial data, and solicit additional data, through surveys sent to mathematics department chairs at the subject institutions. The third phase of the study examined promising programs in greater detail, using in-

depth phone interviews with selected department chairs to explore factors contributing to the success of exemplary programs.

Definitions and Common Abbreviations

What is *quantitative literacy*? Examination of a number of resources fails to yield a universally accepted definition, with many sources relying instead on lists of skills and contexts that should be expected of a quantitatively literate college graduate. Even the term quantitative literacy seems open to discussion, with some authors using *quantitative reasoning*, and others referring to *numeracy*. Although there are subtle semantic differences between these terms, the conceptual construct to which they refer appears to be similar; researchers and authors in the field seem to use the terms nearly interchangeably, with quantitative literacy used most often in the United States. (Numeracy seems to take on that role in publications from authors in other countries.)

Regardless of the words used to denote the construct, the definitions seem to fall into two categories – descriptive and functional. The International Life Skills Survey (as cited in Steen, 2001b) defines quantitative literacy as

> An aggregate of skills, knowledge, beliefs, dispositions, habits of mind, communication capabilities, and problem solving skills that people need in order to engage effectively in quantitative situations arising in life and work. (p. 7)

In a similar but broader definition, the Programme for International Student Assessment (as cited in Steen, 2001b) defines *mathematics literacy* as

An individual's capacity to identify and understand the role that

mathematics plays in the world, to make well-founded mathematical

judgments and to engage in mathematics in ways that meet the needs of

the individual's current and future life as a constructive, concerned and

reflective citizen. (p. 7)

Both of these definitions allude to a number of elements that seem to be common to most

definitions of quantitative literacy – confidence with mathematics, cultural appreciation,

interpreting data, logical thinking, making decisions, mathematics in context, number

sense, practical skills, prerequisite knowledge, and symbol sense (Steen, 2001b, pp. 8-9).

These elements seem to form the core of most contemporary concepts of quantitative

literacy.

In examining courses and programs at subject institutions, this study used the

guidelines set forth by the Committee on the Undergraduate Program in Mathematics

(CUPM, 2004), which stress that effective quantitative literacy programs should foster

student confidence and engagement in mathematics, enhance students' skills in

quantitative reasoning, communication, and problem solving, and promote critical

thinking about mathematical issues arising in work and life. This operational definition

was used throughout the study as a set of criteria by which to judge the success of

quantitative literacy programs and courses.

The other common theme in this study is the concept of an undergraduate *core

curriculum*. Although institutions use various phrases to describe these requirements,

including *distribution* or *general education requirements*, most four-year colleges and

universities require students to achieve a set of competencies beyond their major field through course taking and/or examination. It was the goal of this study to examine the quantitative elements of such core curricula. Not only did this study examine the core curricular requirements for each subject institution, but it examined the courses that could be used to satisfy those requirements, both as presented in institutional catalogs, and as realized through actual course offerings and enrollment.

Many of the terms and organizations to which this study will often refer have lengthy and unwieldy titles. In the interest of brevity and clarity, there are three terms for which the use of acronyms are appropriate in the remainder of this document, except within direct quotes from other sources. Quantitative literacy (and all of its near-synonyms) will be consistently referred to as QL, an abbreviation that is used in many books and articles on the subject.

The other two abbreviations that will be used throughout this document are acronyms for professional bodies concerned with the study of QL. The Mathematical Association of America (MAA) is a professional organization for collegiate mathematics, and sponsored much of the recent research surrounding QL. In particular, a committee of the MAA, the Committee on the Undergraduate Program in Mathematics (CUPM), is charged with ongoing research and recommendations surrounding both mathematical core curricula and programs for students majoring in the mathematical sciences. As mentioned earlier, the recommendations of the CUPM regarding QL education were used as the standard by which programs and courses were evaluated.

Chapter 2. Review of Literature

As mentioned earlier, the mathematics community began to pay some attention to quantitative reasoning as early as the 1950s (MAA, 2004), but most of the current efforts and recommendations related to QL are the result of work begun in 1989 by the CUPM. Consequently, after a brief consideration of early work in the field, this review will focus on the work done in the past twenty years.

In the United States, several professional associations have influenced the developing field of QL. At the forefront is the MAA, and much of the literature on the field is contained in, or refers readers to several volumes published in their "Notes" series from 1999 to 2006 (Gillman, 2006; Gold, Keith & Marion, 1999; Hastings, 2006; Steen, 2004a). Other significant contributions to the field have been made by the American Mathematical Association of Two-Year Colleges (AMATYC), the National Council of Teachers of Mathematics (NCTM), and the National Council on Education and the Disciplines (NCED).

The QL Movement Prior to 1990

One of the first efforts to address mathematical curricula in general undergraduate education came with the publication of the *Universal Mathematics* program in 1954-1958. This program, produced under the auspices of the MAA, was designed as a first-year college course for all students (MAA, 1994). Aside from some limited pilot testing of the program it received little attention, but *Universal Mathematics* seems to have marked the beginning of consideration of QL by the mathematics profession.

The CUPM revisited the question of QL in 1965 with the publication of its *General Curriculum in Mathematics for Colleges* (CUPM, 1965). While this document attempted a synthesis of previous recommendations by the committee and proposed a program of core courses,

> CUPM chooses not to issue the results of its study of the problem as a set
>
> of recommendations made on its own authority. Instead, we hereby
>
> present our findings as a report to the Mathematical Association of
>
> America and seek its acceptance by the Association. (CUPM, 1965, p. 3)

Interestingly enough for this study, the report recognized the challenges faced by small colleges and universities, and focused on outlining a program that could realistically be offered by a department with as few as four faculty members (CUPM, 1965).

The next major push for QL came with a 1982 report developed by a sub-panel of the CUPM. Resulting from a survey conducted in the late 1970s, the panel recommended a "bare minimum of mathematical competencies for all college graduates" (CUPM, 1982, p. 267) including a recommendation for courses focusing on applications and the historical and philosophical foundations of mathematics (CUPM, 1982).

Finally, publication of *Everybody Counts* (National Research Council, 1989) and *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) in the same year helped to bolster the movement toward greater coherence in the mathematics education community. *Everybody Counts* stressed that effective functioning as a citizen in today's world requires that individuals be mathematically literate as well as verbally

literate (National Research Council, 1989). NCTM supported this point of view by

defining

> Five general goals for all students: (1) that they learn to value
>
> mathematics, (2) that they become confident in their ability to do
>
> mathematics, (3) that they become mathematical problem solvers, (4) that
>
> they learn to communicate mathematically, and (5) that they learn to
>
> reason mathematically. (NCTM, 1989, p. 5)

The QL Movement in the Past Two Decades

Also in 1989, the CUPM formed a subcommittee on Quantitative Literacy

Requirements to formulate guidelines for collegiate-level QL offerings, culminating in

the publication of *Quantitative Reasoning for College Graduates* (MAA, 1994). Around

the same time, AMATYC began developing standards for two-year college mathematics

programs to complement those of NCTM and provide a bridge to MAA

recommendations, finally publishing its *Crossroads in Mathematics* in the mid-1990s

(AMATYC, 1995).

Following the emergence of standards and policy documents published by several

organizations from 1989-1995, publication activity in QL diminished for a short time as

institutions and organizations attempted to grapple with the meaning of the new standards

in the practical context of curricular design. By the eve of the twenty-first century,

however, researchers began to publish the results of institutions' implementation of the

1994 CUPM recommendations (Al-Hasan & Jaberg, 2006; Jordan & Haines, 2003; Keith,

1999; Otto, Lubinski, & Benson, 1999; Poiani, 1999; Sons, 1999; Steen, 2001, 2004a).

In fact, faculty at so many colleges and universities wrote about their new QL programs that the MAA gathered some of these writings in *Current Practices in Quantitative Literacy* (Gillman, 2006), which contains articles related to QL program elements from more than twenty different institutions, some of whom were in the subject population for the current study.

Meanwhile, experts in the developing field of QL continued to contribute to the theoretical literature. Two of the most prominent of these were Lynn Arthur Steen and Bernard L. Madison. Between 2001 and 2006, the two (separately or together) authored or edited numerous books and manuscripts on QL (Madison, 2001, 2003a, 2003b, 2004, 2006; Madison & Steen, 2003; Steen, 2001a, 2001b, 2003, 2004a, 2004b). Both are strong proponents of the growing trend toward QL in K-16 mathematics education, but from slightly different perspectives.

Steen's writings focus on the needs of democracy and an information-based society to develop citizens who are adept at reasoning within quantitative contexts. In *Embracing Numeracy* (Steen, 2001), he cites as examples public policy debates surrounding the census and apportionment, the federal budget, and controversies surrounding vote counting in the 2000 U. S. Presidential election.

Madison, on the other hand, concentrates on the primacy of the traditional calculus-oriented curriculum as it draws attention away from efforts to infuse QL within the study of mathematics. In *Two Mathematics* (2004), Madison points out that the traditional mathematics curriculum (geometry, algebra, trigonometry, calculus, or GATC for short) is focused on "the perceived educational needs of future scientists, engineers,

and mathematicians, who comprise approximately one-fourth of the college population"
(Madison, 2004, p. 10). He further notes that since the GATC sequence dominates the
college admissions process through admission requirements and placement testing, it has
come to be seen as superior to any secondary mathematics program focused on QL
(Madison, 2003a), and has become a gateway to higher mathematics at both the high
school and college levels. Unfortunately, he points out, the sequence is structured such
that students who leave the GATC sequence before reaching calculus never gain access
to the truly interesting applications of mathematics, and further, are left with fragmented
algorithmic skills remote from their daily lives (Madison, 2003a).

This study was also concerned with the realities of implementing QL curricula as
well as the theory. Somerville, in response to the 2001 National Forum on Numeracy
sponsored by NCED, discusses policy issues that typically arise at the collegiate level,
claiming that they are "clearly the key to the success or failure of the QL initiative"
(Somerville, 2003, p. 193). She contends that the messages sent by the collegiate
mathematics community to secondary students, parents, counselors, and teachers
unequivocally emphasize the importance of the traditional GATC curriculum and make
little, if any, mention of QL.

Much of the literature on QL grew out of a number of conferences held in late
2001 and early 2002. The first, "Rethinking the Preparation for Calculus," was
sponsored by the MAA in October 2001, and initially focused on students in pre-calculus
and other courses in the sequence terminating in calculus. However, as the conference
progressed, the participants realized that the focus was too narrow and broadened the

scope of the discussions to consider the needs of students for whom a course below calculus was the final mathematics course (Hastings, 2006, p. vii).

The "Curriculum Foundations Summary Workshop" held in November 2001, was the last in a series of twelve workshops that attempted to gather information about the mathematical needs of partner disciplines in undergraduate programs. Sponsored by the MAA committee on Curriculum Renewal Across the First Two Years (CRAFTY), the series produced a guiding document (Ganter & Barker, 2004) designed to aid in the development of interdisciplinary programs in quantitative disciplines such as biology, economics, engineering, and teacher preparation.

In early December, 2001, the Woodrow Wilson Foundation sponsored the "Forum on Quantitative Literacy," to expand the conversation begun by NCED with the 2001 publication of *Mathematics and Democracy* (Steen, 2001b). In this forum, participants considered submitted papers addressing QL in the contexts of citizenship and work, curriculum issues, and policy challenges (Madison, 2003b). The final product of the workshop (Madison & Steen, 2003) contained not only the twelve initial essays but additional manuscripts on similar issues arising during the forum.

The fourth meeting in 2001, "Excellence in Undergraduate Mathematics: Mathematics for the 'Rest of Us'," was sponsored by the American Mathematical Society in December (Fisher & Saunders, 2006). Again concentrating on students who fulfill their mathematics requirement with courses below the calculus level, the workshop brought together faculty from thirty-three mathematics departments to discuss student and faculty demographics, courses offered, successes, and challenges within their

departments. One consensus that arose from the workshop was that "mathematics departments should consider offering several courses at this level [of college algebra] with each designed for one or more of the targeted student populations" (Fisher & Saunders, 2006, p. 272). This notion of differentiating courses to accommodate specific segments of the student population could be problematic for the small college that may be limited by faculty resources to offering one or two sections of a course in any given semester.

Finally, the "Conference to Improve College Algebra" was held in February, 2002, to address the failure of traditional college algebra and transform it into a course "that enables students to address the needs of society, the workplace, and the quantitative aspects of disciplines" (Small, 2006, p. 83).

With so many opportunities for discussing QL and related topics in such a short period of time, leaders in collegiate mathematics were clearly concerned with the way students were being served by the courses below calculus. In an attempt to focus the discussions from earlier meetings into a national initiative, follow-up meetings were sponsored by the MAA. Although some of the recommendations have already been implemented, an ongoing need is "a cohesive plan to identify and publicize model programs that have adapted and implemented these [QL and college algebra] projects" (Gordon, 2006, p. 279). This identification was a major goal of the current study.

The QL Movement Today

Several documents guide recent efforts in QL. The first is the current CUPM *Curriculum Guide* (2004), which outlines recommendations for a number of different

subpopulations of undergraduate students. This document cites the frequent mismatch between the rationale of a traditional college algebra course (to prepare students for further study in mathematics) and the needs of enrolled students. To remediate the disparity, the guide recommends offering suitable courses as alternatives to college algebra, and ensuring the effectiveness of all courses in the undergraduate mathematics curriculum (CUPM, 2004). In particular for general education courses, the recommendations include ensuring that courses foster student engagement and confidence, improve skills in reasoning, problem solving, and communication, and make explicit connection to real-world quantitative topics.

First in *Crossroads in Mathematics* (Cohen, 1995) and later in *Beyond Crossroads* (Blair, 2006), AMATYC developed its own set of standards aimed at improving mathematics education at two-year colleges. The twenty standards in *Beyond Crossroads* are divided into three sets – standards for intellectual development, content, and pedagogy. Advocating for informed decision-making, the document focuses not only on mathematics programs within two-year colleges, but encourages institutions to consider their students' transition issues as they come from secondary education and later transfer to four-year colleges (Blair, 2006).

In general, authors and researchers continue to question how well traditional approaches to college algebra serve the general population of students. Arguing for a change in pedagogy, Gordon (2008) pointed to changing needs of students as well as changes in K-12 pedagogy to motivate a need for college algebra courses to become more conceptual and incorporate realistic contexts. In his work, he relies strongly on the

standards promoted by the MAA (CRAFTY, 2007; CUPM, 2004) and AMATYC (Blair, 2006; Cohen, 1995).

Herriott and Dunbar (2009) take a different tack in their quantitative examination of the educational plans and subsequent course-taking patterns of students enrolled in college algebra, along with the success rate of students (defined as the percentage of students receiving course grades of A, B, or C) in the course. After studying enrollments at eight large universities and two two-year colleges in three states, their findings suggest that a typical college algebra course serves only 5-10% of its students well. Other students encounter a high failure rate and little practical applicability of the course to the type of quantitative reasoning they will need in the future. In conclusion, Herriott and Dunbar stress the need for college algebra courses that "stimulate students' interest in and appreciation of mathematics both as a practical tool and as a domain of human knowledge and intellectual expression" (Herriott and Dunbar, 2009, p. 86).

The Need for the Study

Kirst (2003) claimed that "there are no recent assessments of the status of general education" (p. 109). He cited as the most recent (as of 2003) a 1992 study by Adelman based on the National Longitudinal Study of the 1970s, which reported that students took very few courses that were not specific to their major field.

Since that time, the American Council of Trustees and Alumni (ACTA) has begun conducting a study at irregular intervals of general education requirements at colleges and universities. Denounced by Lynn Steen (2004b), the original study (ACTA, 2004) claimed that 62% of the institutions examined failed to require mathematics. This

assessment was entirely focused on traditional calculus-oriented curricula, and completely ignored the developing trend toward QL. The most current ACTA study (2010) continues this narrow view with an expanded study of seven hundred eighteen institutions, more than one hundred of whom were members of the subject population for the current study. ACTA's statement that "only 61% of colleges and universities require students to take a college-level mathematics class" (ACTA, 2010, p. 17) omits recognition of many programs in QL that exist at institutions around the country. One objective of the current study was to counter this "tunnel vision" by identifying QL programs that exist at small colleges in the U.S.

Another, and perhaps more important, objective was to assist mathematics faculty at small colleges in identifying and evaluating types of programs that may work in their own institutions. In discussing the challenges faced by faculty at small colleges, Moffat (2010) reminds us that "faculty must always do *too much* [italics in original]" (p. 284). Rather than expect already-stressed faculty to investigate the broad array of QL programs independently, this study provided faculty at small institutions with a reference for considering the benefits and challenges of revisions to current offerings within the context of institutions of similar size.

Jeanne Narum, founding Director of Project Kaleidoscope, emphasized that the movement toward QL needed not only to enlist the right people to explore the right questions, but also needed to "take the kaleidoscopic perspective, recognizing that the work is to change the system, not tinker at the edges" (Narum, 2003, p. 239). As Westfall claims, "small colleges have survived by simultaneously adapting to changing

societal circumstances and holding on to their traditions" (Westfall, 2006, p. 7). The consensus in the collegiate mathematics community seems to be that societal circumstances have changed, requiring new approaches to developing quantitative reasoning. The tradition of college algebra as a one-size-fits-all approach to numeracy is one that may need to be abandoned.

Chapter 3. Design of the Study

Research Questions and Purpose of the Study

What approaches are being used to develop quantitative literacy among the general population of undergraduate students at small colleges and universities? Which approaches are consistent with the recommendations of the Mathematical Association of America's Committee on the Undergraduate Program in Mathematics (CUPM, 2004)? What factors contribute to the successful implementation of programs consistent with MAA/CUPM recommendations? How do mathematics departments at small colleges balance the needs of the general population of students along with the needs of student majoring in the mathematical sciences?

As noted earlier, most colleges in the U. S. require students to complete a core curriculum, in addition to studies in their major field(s), before students may receive a baccalaureate degree. The quantitative elements in these core curricula were the primary focus of this study.

Procedures

Research design. The nature of the research question required a primarily qualitative approach. Although the ultimate results of the study focus on rich descriptions of a small number of specific QL courses and programs, it was necessary to examine a wide variety of institutions in order to identify these programs. One could think of the research design as an elimination process, or funneling, as suggested by Erickson (as cited in Miles & Huberman, 1994). While the first two stages of data collection, discussed in Chapters 4 and 5, yielded some quantitative information in the

form of summary counts aimed at providing context for the results of the study, the bulk

of the findings consists of narrative descriptions and associated variable analysis of

successful QL courses and programs.

Preliminary data was gathered from college and university catalogs, and from

several independent data sources (AFT, n.d.; Barron's, 2010; College Board, 2010a) by

the researcher. In addition to data on course offerings and core curricular requirements,

the first phase of the study included demographic information on enrollment, admissions

selectivity, finances, accrediting agency, and on-campus residency of students. See

Appendix A for a sample of the form used in initial data collection for each institution.

While initial data provided some information as to the character of an institution

and apparent type of program in effect at each institution in the study population, the

document-based evidence raised many questions, such as the pathways for students to

complete requirements, the extent and frequency of course offerings, and the institution's

perspective on QL. Therefore, in Phase 2 of the data collection, an essential tool in

compiling complete information for an institution was direct e-mail contact with and

completion of an online survey by the mathematics program chair, to obtain further

information about the actual functioning of the intended program as stated in the catalog.

In a number of cases, the mathematics program chair requested that the researcher contact

a different individual at a subject institution, so that Phase 2 data for these institutions

was obtained from a person designated by the mathematics program chair.

The third phase of the study concentrated on programs considered particularly

promising (and consistent with best practices in QL as defined by MAA and CUPM

recommendations) based on initial data and responses from department chairs. For these programs, the researcher conducted in-depth phone interviews with mathematics program chairs to explore factors contributing to the success of courses and programs, challenges faced in initial implementation, and refinements in the program since implementation. This phase of the study produced case study descriptions and variable analysis of successful programs (as judged against the CUPM recommendations) contained in Chapters 6 and 7, as well as recommendations for other institutions implementing or revising QL programs or courses.

Subject population. For the purpose of this study, a small institution was defined as one for whom the full-time undergraduate enrollment in the fall of 2009 was no more than two thousand students. This specific undergraduate enrollment was chosen for logistical purposes, as it is the level of enrollment used by the College Board's searchable database to define a small institution (College Board, 2010a). In recognition of potential conflicting demands on many mathematics departments, this study further restricted itself to small institutions that also offer an undergraduate major in the mathematical sciences. Although mathematics was a common major field, institutions offering undergraduate majors in applied mathematics, mathematics education, and statistics were also included in the population.

Four hundred sixty-four institutions were initially identified as possible members of the population described above, by cross-referencing search results from the College Board's College Matchmaker search engine (College Board, 2010a) with examination of Barron's Guide to American Colleges (Barron's, 2010) and the American Federation of

Teachers' Higher Education Data Center (AFT, n.d.). Data on the AFT site is obtained

directly from institutional reports to the U. S. Department of Education, and institutions'

full-time undergraduate enrollment as reported for the fall of the 2009-10 academic year

was used as the determining factor in including institutions based on enrollment.

During the first phase of data collection, thirty-six institutions were eliminated

from further investigation for a variety of reasons. Thirteen institutions were found to

have full-time enrollments greater than two thousand undergraduates, and an additional

twelve either had no major in the mathematical sciences or were not accepting new

majors, leaving the future of the major in doubt. Five institutions in the study offered no

courses below the level of calculus, five had missing or incomplete web presences that

made data collection impractical, and one institution had unfortunately ceased operations

in the summer of 2010. These deletions left a total of four hundred twenty-eight

institutions to be considered in the first phase of the study. The complete list of Phase 1

institutions is included as Appendix B.

The institutions in the study were geographically diverse, being located in forty-

four of the fifty states and the District of Columbia. Only Arizona, Delaware, Hawaii,

Nevada, Utah, and Wyoming contained no colleges and universities that met the criteria

for the study. A breakdown of the number of institutions within broad geographic

regions appears in Table 1.

Region	Number of Institutions
New England & Mid Atlantic (CT, DE, DC, MD, ME, MA, NH, NJ, NY, PA, RI, VT)	95
Southeast (AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV)	125
Great Lakes & Plains (IN, IL, IA, KS, MI, MN, MO, NE, ND, OH, OK, SD, TX, WI)	168
Rocky Mountains & Far West (AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY)	40

Table 1. **Geographic distribution of subject institutions**

Territories of the U.S. were not included in the search for subject institutions. Aside from Puerto Rico, institutional data on schools outside the United States was extremely limited in both of the resources used to identify subjects for this study. Many of the colleges and universities in Puerto Rico, while identifiable based on search resources, were found to publish their web pages in Spanish, a language unfamiliar to the researcher.

Data collection. The initial phase of this study was entirely document-based. In this phase, the researcher examined the web-based catalogs of all of the subject colleges and universities for basic demographic information about the institution, the name and e-mail address of the mathematics department chair, and data on their course offerings below calculus in the form of credit hours, prerequisites, and course names and descriptions. In the five cases in which an institution's undergraduate catalog for the 2010-11 academic year was not accessible online, the institution was eliminated from

further study. Supplementary information such as enrollment, selectivity, finances, and residency was gathered from independent data sources (AFT, n.d.; Barron's, 2010; College Board, 2010a). All Phase 1 data was organized for later retrieval and analysis using relational database software. The form used for the initial data collection is reproduced as Appendix A.

Following initial review of an institution's catalog and supplementary data, it was necessary to contact the colleges and universities in the study for further information. Mathematics program chairs at subject institutions were contacted by e-mail and asked to complete a brief online survey to answer specific questions about course descriptions, prerequisites, course enrollments, section counts and instructor assignments, as well as to answer general questions related to placement, course-level quality control, plans for new course offerings, and views on QL. A sample e-mail to a mathematics department chair, requesting a response via an online survey, is contained in Appendix C. While the actual online surveys were customized for each institution, a sample survey including the questions to be asked has been reproduced as Appendix D, and supplemental institution-specific questions applicable to question 3 of the sample survey are listed in Appendix E. Questions numbered 6 through 15 in the sample survey were asked of all institutions.

Since answers to questions regarding actual course offerings were solicited by direct e-mail and online survey, a substantial non-response rate was expected in the second phase of the study. If no response was received to the initial e-mail, information was requested via a second e-mail contact after an elapsed period of several weeks. In cases where the second e-mail contact failed to yield a response, the researcher assumed

that the mathematics program chair had no interest in providing clarification of Phase 1 data, and no further attempt was made to gather additional information. This resulted in the study population being self-sorted into two groups – those for which complete data was available for both Phase 1 and Phase 2, and those for which the only data was document-based. Although the initial hope was for a survey response rate near twenty-five percent, resulting in complete data from at least one hundred institutions, the final response rate was greater than forty percent, with one hundred seventy-five institutions providing complete data for Phase 2 of the study.

The third phase of data collection was limited to those institutions that seemed to offer QL programs or courses consistent with the recommendations of the CUPM, based on information gathered in the first two phases of the study. Programs selected for further investigation in Phase 3 of the study were those which, in the judgment of the researcher, are likely to foster student engagement and confidence with mathematics, enhance student skills in mathematical reasoning, communication, and problem solving, and promote critical thinking about mathematical issues arising in work and life. This judgment was based primarily upon data from the survey contained in Phase 2 of the study, which sought specific information about courses or programs identified during Phase 1 that showed potential for meeting these criteria. Keeping in mind that program continuation depends upon sustained enrollment at many institutions, consideration in Phase 3 was also limited to programs enrolling a minimum of approximately ten percent of an institution's total undergraduate population in the fall term of the 2010-11 academic year. Programs or courses at thirteen institutions (3% of the original population, or 7.4%

of the Phase 2 sample) met these criteria and were contacted for in-depth interviews in Phase 3. Of the thirteen institutions, three failed to respond or declined to participate, and programs at an additional three colleges and universities were judged not to meet the criteria for inclusion upon analysis of the interview data.

Mathematics program chairs at institutions selected for Phase 3 were contacted again by e-mail, to request an appointment for a phone interview. In addition to confirmation of the researcher's impressions based on the first two phases of the study, this phone interview probed more deeply into the chair's perception of the reasons for success of their programs. In particular, the researcher sought to determine whether a program owes its CUPM consistency and strong enrollment to design features, or to other characteristics possibly unique to a particular institution, such as a single charismatic faculty member. A list of guiding questions for the in-depth Phase 3 interviews has been reproduced in Appendix F.

Procedure. As mentioned above, this study was conducted in several phases. The first phase, document-based data collection, was piloted using a small group of subject institutions. The purpose of this pilot study was to refine the data collection instrument included as Appendix A. After piloting and refinement of the data collection instrument, document-based research of all subject institutions was conducted in the spring of 2011.

Following completion of Phase 1, the researcher contacted each institution's mathematics program chair by e-mail, asking him or her to complete the online survey (Appendix D) to clarify questions raised by the catalog and provide additional

information about the institution's practices and attitudes related to QL. The third phase, in-depth phone interviews with mathematics program chairs, occurred during the late fall of 2011.

Data Analysis. Analysis of document-based data was ongoing throughout both of the first two phases of the study, and is described and presented in Chapter 4. Analysis of Phase 1 data examined not only demographic variables for the population of four hundred twenty-eight institutions, but course offerings and quantitative general education program requirements at these institutions as well.

Survey data in Phase 2 of the study served two purposes. The first, using specific information related to course offerings and enrollments, was to enable the researcher to identify candidates for Phase 3 inclusion. The second, and more important, purpose was to gather data related to the operations of mathematics departments at respondent institutions and gain insight into collective opinions surrounding QL in the undergraduate curriculum. The analysis of Phase 2 survey data is contained in Chapter 5.

Much of the analysis and reporting is in the form of qualitative data related to particular institutions' programs and courses. Courses and programs selected for inclusion in Phase 3, and how they meet contemporary best practices in developing quantitative reasoning in undergraduates as defined by the CUPM (2004), have been summarized in rich narrative descriptions in Chapter 6. Further analysis of these programs using a variable-oriented approach is presented in Chapter 7.

Ethical considerations. Since Phase 1 of this study was primarily concerned with institutions, rather than human participants, and data was obtained from publicly

available documentary sources, it did not require approval by an Institutional Review Board. In collection of the Phase 2 survey data, the request for opinions in addition to facts, and identifiability of the respondent institutions and individuals necessitated the use of active informed consent procedures. Informed consent was obtained from respondents at the time of survey completion, and the informational statement and consent mechanism used are shown in Appendix D as they appeared on the first page of the online survey. For the in-depth interviews in Phase 3, full informed consent procedures were followed, and the informed consent document is reproduced as Appendix G.

The identities of individual institutions and program chairs responding to e-mail inquiries, surveys, and interview requests have been kept confidential in the reporting of this research, and reporting of the study includes only general demographic information necessary to place courses and programs in their institutional contexts. In the interest of maintaining this confidentiality, all institutions and interview respondents described in the in-depth case studies have been assigned a pseudonym, and data linking this pseudonym to the actual identity of an institution or person is accessible only to the primary investigator in this study.

Trustworthiness. As a qualitative study, the trustworthiness of the conclusions is based on apparency, verisimilitude, and transferability as described by Connelly and Clandinin (1990). The internal validity and reliability of the data was strengthened by the use of cross-checking information found in institutional catalogs with mathematics program chairs, and ultimately by the development of case studies from direct personal communication.

Data for this study was obtained from several sources. The initial document-based data collection was from publicly available college catalogs and other data sources, and may be verified independently by anyone choosing to do so. Confirmation of the data obtained from documentary sources was sought from mathematics program chairs, who are in an optimal position to understand the facts behind the document-based data. Therefore, the Phase 2 survey instrument, while collecting additional data, also served to verify and correct document-based data from Phase 1. Course enrollment data from Phase 2 served as further verification of the degree to which the intended program of general education in mathematics is actually achieved.

The direct contact between the researcher and program chair in Phase 3 was a further instance of verification of data from earlier phases, and the real-time interaction between the researcher and respondents during in-depth interviews allowed for prompt confirmation of the researcher's written notes. Finally, Phase 3 respondents were invited and given several weeks to read and respond to the final case study report on their institution. This member checking revealed some small errors and misperceptions of the researcher that were corrected in the final narrative and analysis.

Piloting of the data collection instrument using a small number of institutions allowed the researcher to anticipate some of the questions that would be generated by the data, allowing for the refinement of data collection instruments, which in turn enabled greater consistency in data collection for the primary study.

Judgments of external validity rest entirely with the reader of the completed study. This document provides rich, descriptive data to enable the reader to evaluate

possible connections between the research and the reader's own circumstances. This

research does not attempt to build theory or make any claim to generalizability, but

instead presents a view of the state of QL efforts at small colleges in the 2010-11

academic year, that may guide readers to further analysis of their own institutions.

Limitations and constraints. The reader is cautioned to recognize that the

methodology used in this study may limit generalizability of its findings. In particular,

the study design made no use of random sampling procedures or quantitative comparison.

Instead, the research used a funneling process of examining the population of all small

colleges and universities, narrowing the focus in Phase 2 to survey respondents, and

finally making deliberate decisions regarding an institution's suitability for Phase 3.

Further, it should be noted that the survey results in Phase 2 were voluntary

responses. There may be common characteristics shared by non-respondents that would

yield conclusions other than those reached in this study, or common characteristics of

respondents may have presented a set of viewpoints that are not necessarily

representative of mathematics faculty at small colleges. The most likely of these

characteristics may be the level of interest in the topic of the study; those interested in QL

may have been more likely to respond to the Phase 2 survey.

This study was not intended to produce theories about approaches to mathematics

being used in core curricula at small colleges and universities. Instead, this study may

serve as a reference for mathematics departments and faculty to use when evaluating and

revising their own programs. It may also raise questions within the collegiate

mathematics community about challenges and opportunities in establishing QL programs at small institutions, which may in turn lead to further research.

Chapter 4. Institutions, Courses, and Programs

The initial phase of data collection, the results of which are presented in this chapter, was a document-based examination of online college catalogs and other freely available institutional demographic information designed to provide an overview of general education programs and courses at subject institutions, and of the institutions themselves. Analysis of general education program requirements, course descriptions, and course offerings in this phase gave preliminary answers to the first and second of the research questions, and provided context for the discussions in later chapters.

Institutions

The institutions in the study were geographically diverse, being located in forty-four of the fifty states and the District of Columbia. Only Arizona, Delaware, Hawaii, Nevada, Utah, and Wyoming contained no colleges and universities that met the criteria for the study. A breakdown of the number of institutions within broad geographic regions appears in Table 1, presented in Chapter 3.

While institutional size ranged from only 190 full-time undergraduate students to 1,996 (recall that two thousand was the maximum size for inclusion in the study), approximately sixty-five percent of the population enrolled more than one thousand full-time undergraduates in the fall term of 2009 (Figure 1). The mean enrollment for the group was 1,202, with a standard deviation of 416 students.
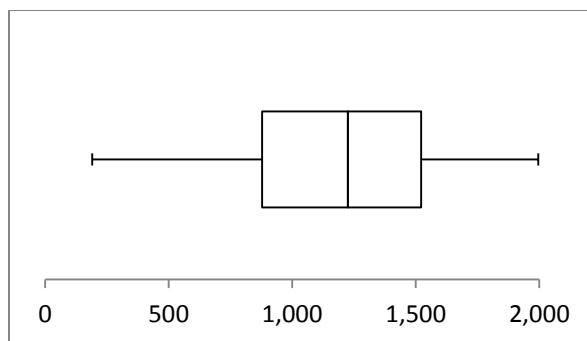
Figure 1. **Full-time undergraduate enrollment, Fall 2009**

In addition to considering the full-time undergraduate enrollment for inclusion in the study, the character of a campus as commuter or residential may be a factor in course offerings. This character could affect the degree to which students interact with each other, and the level of interaction between students and faculty. These interactions, in turn, have an impact on pedagogical practices that may encourage (or discourage) student collaboration as a component of effective programs in quantitative literacy. Two measures were used to consider the character of the student community in the subject institutions.

The first measure of campus community was the percentage of undergraduates residing on campus (College Board, 2010a) which, while not available for all institutions in the study, showed some interesting patterns. Of the 407 schools for which this data is available, nearly three-quarters reported at least half of their undergraduates living on-campus (Figure 2).
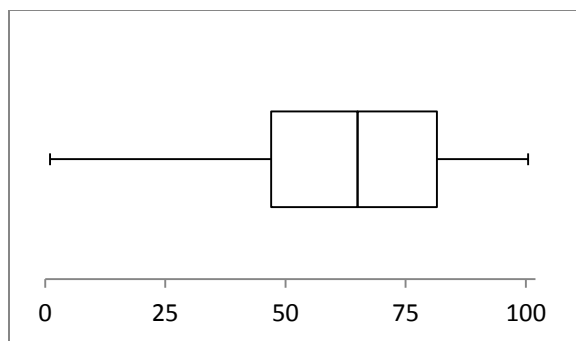
***Figure 2.* Percent of undergraduates living on campus**

The inability to distinguish between students who commute and those who live in nearby, but off-campus housing, make it difficult to determine the impact non-resident students might have on a campus community.

Another metric that could be used to address the nature of the campus community is the ratio of full-time undergraduate students to full-time-equivalency units (FTEs). Since part-time students make up a large percentage of undergraduates at some institutions, this ratio attempts to quantify the proportion of credit hours attributable to full-time students versus part-time students. Although there was some variation between institutions, this ratio indicates that at two-thirds of the institutions, full-time undergraduates account for at least 95% of credits attempted. At only eighteen of the institutions was this ratio less than 80%. The fact that this ratio is high at most of the subject institutions reduces the likelihood that the presence of part-time students will have a significant impact on campus community. It is worth noting that, since the population includes only small institutions (most of them privately funded), campus

community and residential life may be significant marketing factors supported by the

individual college and highly valued by students and alumni (Hoover, 2011).

Data was collected on several other demographic measures, specifically gender

and ethnic distributions. Most schools in the study were coeducational, although a few

had enrollments consisting primarily (or exclusively) of men or women. A summary of

the breakdown of institutions by gender appears in Table 2.

Gender Balance	*% of Institutions*
Males more than 90% of students	0.7
Males between 65-90% of students	1.0
Co-educational	75.4
Females between 65-90% of students	15.9
Females more than 90% of students	7.0

Table 2. **Distribution by gender**

Racial and ethnic diversity is more challenging than gender to summarize in a single

measure or table. The data collected included the percentages of both white and black

non-Hispanic students, and Hispanic students as reported to the U.S. Department of

Education (AFT, n.d.). Instead of attempting to incorporate all of the possible ethnic

categories, Table 3 shows the distribution of institutions by the percentage of white, non-Hispanic students.

Percentage of White, Non-Hispanic Students Reported	*% of Institutions*
More than 90%	2.8
65-95%	67.2
36-64%	20.4
10-35%	4.0
Less than 10%	5.6

Table 3. **Distribution by percentage of white, non-Hispanic students**

The final demographic characteristics collected were two measures of the academic quality of the students at each institution. The selectivity rating (Barron's, 2010) is a measure of the difficulty of gaining admission to an institution, and is summarized in Table 4.

Selectivity Rating	% of Institutions
Noncompetitive (over 98% accepted)	4.4
Less Competitive (85-98% accepted)	9.9
Competitive (75-85% accepted)	53.2
Very Competitive (50-75% accepted)	21.7
Highly Competitive (33-50% accepted)	5.4
Most Competitive (under 33% accepted)	5.4

Table 4. **Distribution by selectivity rating**

Students' high school ranking gives a slightly different view of the quality of students at an institution. Rather than incorporating the market demand for a particular institution, as does the selectivity rating, high school rank assesses students' presumed academic preparedness solely in relation to their peers. The College Board's (2010a) search engine provides the percent of freshmen in the top ten percent of their high school class for many of the institutions in the study. This data is summarized in Table 5.

Percent of freshman in top 10% of high school class	% of Institutions
80-100%	1.7
60-79%	4.5
40-59%	7.5
20-39%	37.6
0-19%	48.7

Table 5. **Distribution by high school rank**

It should be noted that freshman high school rank data was not available for sixty-nine of the institutions in the study. For some schools, no ranking data was provided at all, while for others, the "top 10%" category was missing from the available data. When other categories, such as "% of freshmen in top 25% of HS class" were shown, the absent "% of freshmen in top 10% of HS class" was interpreted as missing data. If its exclusion instead means that zero percent of freshman were in the top decile of their high school class, this missing data may exacerbate the tendency for students at the subject institutions to fall in the lower categories of high school rank.

In addition to collecting demographic data regarding the student population, information was collected regarding the financial status of each institution. Twenty-six

of the institutions in the study are publicly funded; the limitation on undergraduate

enrollments served to eliminate most public institutions from this study. Because many

of these public institutions are branch campuses of larger state university systems (and

presumably have the resources of the state universities on which to draw), this discussion

of financial status will be limited to those four hundred two colleges and universities

under private control. To enable comparisons between institutions of different size, all

financial data is reported on the basis of dollars per full-time-equivalent (FTE)

enrollment. It should be noted that a major recession began in the United States in early

2008, with a sharp downward turn in September of that year.

Data was collected on both operating revenues and expenditures per FTE for the

2008-09 academic year, and net operating surplus or deficit was calculated from those

values. This period of time may have shown the early effects of recession on net

operating income for colleges and universities. Although the mean operating surplus was

$1,130 per FTE, results of operations for 2008-09 varied widely, with a standard

deviation of $5,197. Thirty-six percent of the privately-funded institutions in the study

recorded operating deficits for the year, with the largest deficit being $24,883 per FTE.

The largest operating surplus for any institution was $31,035 per FTE. Although there

were some institutions with very large deficits or surpluses, the results of 2008-09

operations at the middle 50% of institutions were concentrated in a narrow range, from a

deficit per FTE of $1,155 to a surplus per FTE of $3,307.

The more significant impact of the recession was found in the endowment

balances of institutions, reported per FTE at the close of the 2008-09 academic year. The

downturn in September of 2008 caused major declines in the value of most endowments.

Consequently, data reported here related to endowment balances may be unusually low.

The middle 50% of institutions reported endowment balances between $8,351 and

$43,475 per FTE, with a median of $17,613.   Like operating surplus, endowment

balances varied widely, and were strongly skewed toward the many large values, with a

mean of nearly $50,000.

Curiously, there appears to be a slight negative relationship between operating

surplus and endowment balance, as shown in the scatterplot labeled Figure 3. This

impression is confirmed by analysis of the correlation between these two variables, which

is statistically significant ($p < 0.001$). It is possible that schools that felt financially

secure because of high endowment balances were more willing to risk operating at a

deficit for a short period of time than schools with relatively low endowments.
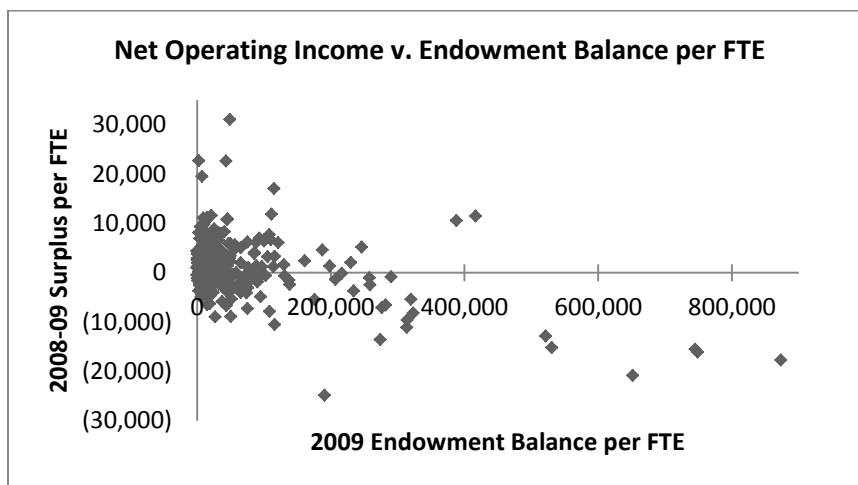
Figure 3. **Operating income versus endowment balance**

In summary, the "typical" institution in this study has a full-time undergraduate enrollment between 1200 and 1300 students, of whom approximately two-thirds live on campus. The college is coeducational, approximately 25% of its students are students of color, and it accepts between 75 and 85% of its applicants, of whom only a small portion graduated near the top of their high school class. It is privately funded with an endowment balance per FTE of about $20,000 at the end of the 2008-09 academic year, and it ended that year with an operating surplus of approximately $1,000 per FTE.

Courses

At each institution, all courses below the level of calculus were classified during initial data collection, and these classifications were reviewed during data analysis. The initial classification of courses was made using a preliminary classification scheme in relation to other courses at the same institution. This classification considered the programmatic elements of course sequencing and prerequisites in addition to course content.

During the analysis phase, courses were considered without regard to institution or program, and classification relied strictly on catalog course descriptions. All courses given a particular preliminary classification were considered at the same time, and course classifications were refined and expanded to reflect the breadth of courses found during initial data collection. This review of similar courses in proximity to each other, rather than in the context of the institution, served to increase the consistency of course classification across institutions. A significant exception to final classification in isolation from institutional context was in courses initially classified as content courses

designed for pre-service elementary school teachers. Many institutions offer a two-course sequence which, taken together, appear consistent with the content strands of *Principles and Standards for School Mathematics* (NCTM, 2000). When such a grouping was found during reclassification, all courses in the sequence were classified as "Math for Teachers." The final list of course type classifications, along with their descriptors, is found in Appendix H. These classifications were then grouped into the following clusters of related courses:

- Traditional – including courses from basic mathematics through pre-calculus and trigonometry, typically designed to prepare students for calculus

- Statistics – including standard courses covering probability and inference, as well as statistics and experimental design courses below and above the standard level

- Quantitative Literacy – including courses focused on mathematical modeling, quantitative reasoning, and quantitative topics courses

- Professional – including courses designed for students majoring in particular fields, typically business, computer science, or education

- Other – including courses not classified into other clusters, such as geometry, history, logic, and other courses offered by mathematics departments

A few institutions offered quantitative courses beyond the mathematics department, particularly in the areas of basic skills or general education core courses. When noted, these courses were recorded and classified as if they were mathematics courses. The exception to this is courses distributed across the partner disciplines that

satisfy quantitative requirements in core curricula. The logistics of identifying these courses is beyond the scope of this research.

A total of 3,188 quantitative courses below calculus appeared in the catalogs of the subject institutions, most offered by mathematics departments but some, as noted above, appearing in the areas of academic support or core curriculum requirements. On average, the institutions in the study offered 7.4 courses below calculus, ranging from a minimum of one course to a maximum of eighteen courses.

After classifying courses into clusters, the study examined both courses offered and courses acceptable for the core curriculum at each institution. Table 6 summarizes the percent of all institutions offering courses in the five clusters. In addition, of the 395 institutions whose catalogs specified courses acceptable for the general education curriculum, the percentage of institutions accepting at least one course in the cluster for purposes of general education is listed in the table.

Cluster	*% of Institutions Offering Courses in Cluster (of 428)*	*% of Institutions Accepting Courses in Cluster for Core Curriculum (of 395)*
Traditional	87.6	73.2
Statistics	87.6	68.9
Quantitative Literacy	74.1	70.4
Professional	76.9	52.9
Other	44.9	28.9

Table 6. **Course offerings and general education acceptability**

It is evident from the table that a greater proportion of institutions offer courses in the traditional and statistics clusters than in the quantitative literacy cluster, and the difference is statistically significant ($p < 0.01$). While fewer than three-fourths of the institutions in the study offer courses in the QL cluster, the proportion of institutions accepting those courses for general education credit is on a par with the traditional and statistics clusters.

One hundred ninety-eight (or 46%) of the institutions examined offered a course classified as "Quantitative Reasoning," the catalog description of which appeared to

promote Steen's definition of quantitative literacy as "an aggregate of skills, knowledge, beliefs, dispositions, habits of mind, communication capabilities, and problem solving skills that people need in order to engage effectively in quantitative situations arising in life and work" (Steen 2001, p. 7). A further 118 institutions (or 28%) offered courses classified as "Mathematical Modeling" or "Quantitative Topics," both of which may contain significant elements of QL.

Programs

The study also examined the core curricular (also known as general education) requirements at each of the subject institutions. While some institutions either had no core requirements at all, or provided students with curricular choices allowing them to avoid quantitative courses, the majority of schools required at least one quantitative course within their core curriculum. Table 7 provides a summary of quantitative core requirements.

Number of Quantitative Courses Required for Core Curriculum (for B.A. degree)	*% of Institutions*
No quantitative courses required; no minimum competency requirement	9.6
No quantitative courses required; minimum competency requirement	4.2
One quantitative course required, not including minimum competency requirement	76.5
Two quantitative courses required, not including minimum competency requirement	8.9
Three or more quantitative courses required	0.7

Table 7. **Quantitative courses required for Bachelor of Arts degree**

As can be inferred from Table 7, some institutions mandate minimum competency for all students. Approximately thirteen percent of colleges and universities in the study require students to demonstrate a minimum level of quantitative skill in addition to the quantitative core requirement (if any). Typically, students may satisfy competency requirements by internal testing (placement or exemption), external testing (AP, SAT, or ACT scores), transfer credit, or course taking. A few institutions exempt students from

minimum competency requirements based on evidence from the student's high school transcript.

At approximately five percent of institutions, students may be exempt from core quantitative requirements (beyond minimum competency requirements that may exist), allowing them to bypass these courses throughout their program. In most cases, this exemption is specified as AP or transfer credit, but a few institutions exempt students from quantitative core requirements based solely on SAT or ACT scores.

Beyond specific quantitative requirements, fifty-six programs require additional courses in the sciences. These distribution area requirements typically allow students to choose between mathematics, computer science, or the natural and physical sciences. Courses satisfying general core requirements in the sciences could be construed as containing elements of QL. Within programs requiring additional courses in the sciences, approximately 45% require one additional course, 42% require two additional courses, and 13% require three or more additional courses. Conversely, at six institutions (1.4%) core requirements are structured so that it is possible for students to completely avoid all of the sciences, including mathematics.

Rather than treating QL in the isolation of mathematics and statistics courses, it has been suggested that distribution of quantitative reasoning throughout the partner disciplines might provide students with broader perspective on the applications of mathematics to life and, in particular, quantitative aspects of their chosen field of endeavor (Diefenderfer, Doan, & Salowey, 2006). General education requirements at twenty-four of the institutions examined (or 5.6%) required students to take quantitative

courses distributed across the curriculum. While most of these required only one course in a partner discipline, four schools required two or more distributed quantitative courses.

In the course of this research, some programs were noted that offered courses in the Quantitative Literacy or related Statistics clusters, but failed to accept those courses for general education credit. At sixteen institutions, courses in the Quantitative Literacy cluster were listed in institutional catalogs, but were not acceptable for core curriculum credit. For Statistics courses, the number was higher, with seventy-five institutions offering statistics courses without applicability to the core curriculum. Particularly in the case of statistics, these courses may be offered as service courses for major requirements in partner disciplines.

By focusing on the demographics of all institutions in the population, and the courses and programs offered via their institutional catalogs, this chapter provided a global context for the study. In the following chapters we will examine more closely the actual practices and opinions related to QL at small colleges and universities.

Chapter 5. Mathematics Departments: Staffing, Operations, Plans, and Opinions

The second phase of this study was a survey of mathematics department chairs, sent to all four hundred twenty-eight of the institutions identified in Phase 1. The e-mail inviting mathematics department chairs to participate, along with copy of the survey and supplemental institution-specific questions, are reproduced as Appendices C, D, and E, respectively. The survey served two purposes, the first being to clarify information gathered during the document-based data collection of Phase 1 of the study, and the second to gather additional information about course enrollments, departmental staffing, plans for new courses, and opinions about institutional programs and QL in general.

Although the original design of this study anticipated a survey response rate near twenty-five percent, or approximately one hundred responses in Phase 2, the actual response rate substantially exceeded that projection. One hundred seventy-five responses were received following the initial invitation (and a subsequent reminder to non-responders), for an ultimate response rate of over forty percent. This high voluntary response rate may indicate a strong interest in the subject of the study among college mathematics department chairs.

Early questions in each survey were customized for each institution, soliciting clarification of data gathered in Phase 1 and information about course sectioning and enrollments in the fall semester of 2010. These institution-specific questions are shown on the survey in Appendix D as questions 3 through 6, along with the supplementary list of questions in Appendix E. Questions asked of all survey respondents (beginning with question 7 of the survey in Appendix D) related to the operations of the department,

including staffing, graduates, placement procedures, plans for new courses, and opinions about QL, both at their own institutions and in general.

Operations

   Departmental staffing. The first two general questions (numbered 7 and 8) were designed to gather information about the size of each respondent's mathematics department, both in terms of the number of full-time faculty and in the number of majors graduating each year. Among the subject institutions (all of which had full-time undergraduate enrollments less than two thousand students), the number of full-time mathematics faculty ranged from one to fifteen, with a median of four. In general, survey information related to the number of Fall, 2010, sections of mathematics classes taught by adjunct or part-time instructors indicates that many institutions rely heavily on part-time instructors to teach many of their courses below calculus.

   However, it may be more meaningful to examine faculty size in relation to the total number of full-time undergraduates at each institution. The ratio of the number of full-time undergraduates to the number of full-time mathematics faculty members showed wide variation, with a minimum of 101 and a maximum of 1,492 students per full-time math faculty member. However, the middle 50% of institutions fell into a fairly narrow band, between 214 and 400 students per full-time math faculty member. A boxplot of this data is shown in Figure 4.
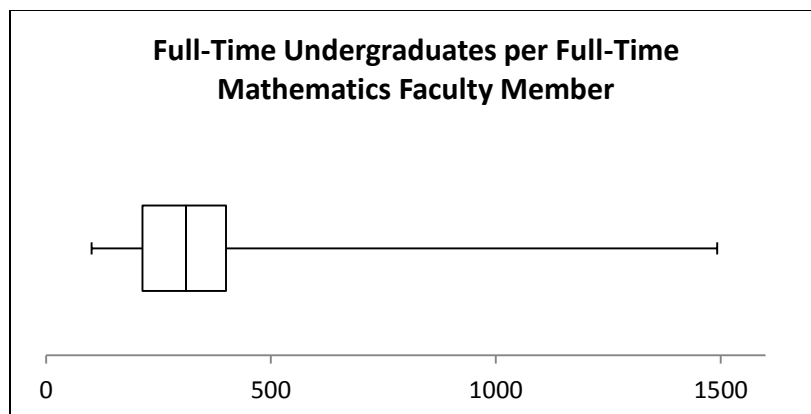
Figure 4. **Ratio of F/T Undergraduates to F/T Mathematics Faculty**

Suspecting that faculty size may vary with the number of quantitative courses required by an institution's core curriculum, a similar analysis was conducted on only the college and universities requiring exactly one quantitative course in the general education curriculum, which accounted for approximately 74% of the respondent institutions. The results of examining this subset of respondent institutions were similar to those of the entire group, with the middle 50% of institutions reporting between 220 and 388 students per mathematics faculty member.

Even considering the number of mathematics majors graduating each year made little difference in the number of full-time mathematics faculty. We might hypothesize that mathematics departments granting a comparatively large number of degrees each year might receive greater staffing support from the institution, but this proved not to be the case. To test this hypothesis, the researcher created a ratio of "Courses per Full-time Mathematics Faculty," as follows:

1) Number of Full-Time Undergraduate Students multiplied by Number of Quantitative General Education Courses Required

2) Number of Degrees Granted in Mathematics Each Year multiplied by 12 (chosen as an estimate of the average number of courses in the mathematics major, based on a 36-credit major requirement)

3) Sum of (1) and (2) divided by the Number of Full-Time Mathematics Faculty

This ratio takes into account not only mathematics courses taken by the general population of undergraduates (one course in four years, for most institutions), but the comparatively greater number of courses taken by relatively few mathematics majors. Like earlier calculations, the middle 50% of institutions fell within a narrow range of 188 to 408 courses offered per full-time mathematics faculty member.

Student placement and quality of incoming students. Many of the survey respondents indicated that their mathematics departments use a combination of methods to place incoming students in mathematics courses. The various resources used by mathematics departments are summarized in Table 8. It should be noted that many respondents indicated more than one resource used for placement purposes, so the total number of users is greater than the number of survey respondents.

Placement Resource	Number of users
SAT or ACT scores	92
Internally-developed placement test	45
Evaluation of secondary transcript	40
Advising and/or personal interview	28
Commercial placement test	22
No placement procedure – all incoming students take common course	1

Table 8. **Placement resources used by survey respondents**

This researcher was surprised to note that thirty-four of the respondent institutions (or

nearly 20%) reported using SAT-M or ACT-M as their sole mechanism for placing

incoming students in the appropriate level of mathematics course. This is despite

recommendations by the College Board that "using test scores as the sole basis for

important decisions affecting the lives of individuals, when other information of equal or

greater relevance and the resources for using such information are available" (College

Board, 2010b, p. 10) should be avoided, and that "users are encouraged to consider scores

in conjunction with other factors such as students' grades, courses taken, … personal

statements, [and] interviews" (College Board, 2010b, p. 3). Similar cautions are presented by the ACT organization (ACT, 2011).

Although the survey avoided soliciting specific information on the mathematical preparation of incoming students, approximately twelve percent of respondents commented on student preparedness or motivation within their survey responses. The survey quotations below capture the generally negative feelings of many respondents:

> From my perspective, the bulk of the change in the classroom experience must come from the students. This means that the onus is on our K-12 educational system to not simply pass out diplomas like candy. A teacher, no matter how good, cannot teach when students do not wish to be taught and believe from their K-12 experience that math is a matter of short-term memorization and an almost mindless application of algorithms. (Confidential survey response, 2011)

> We have very weak students, generally. In that sense our curriculum does not serve them well because many are not prepared for college level math courses. Our university has been unable to afford the staff to begin a developmental program…We have tried very hard to maintain academic standards despite a weakening student population… There needs to be more faculty development in this area. Mathematicians are trained in higher mathematics, not teaching elementary or remedial mathematics. It is often not a good fit. (Confidential survey response, 2011)

We have noted a decline in student preparedness to do mathematics that

do not require a multiple-choice answer. Students are unable to explain

themselves or even have the right vocabulary to ask the question they

have. Thus we have an even steeper hill to climb at the undergraduate

level. (Confidential survey response, 2011)

Incoming math reasoning abilities of students continues to decline, and the

difference in abilities between the strong and weak students is getting

bigger. This heterogeneity makes it more and more difficult. (Confidential

survey response, 2011)

I would like to see students coming in with better quantitative skills (basic

use of fractions, decimals, etc) and basic algebra. Their attitude toward

mathematics is in general somewhat negative, making motivation difficult.

(Confidential survey response, 2011)

We do not do well with remediation of pre-college level skills… We find

ourselves challenged to offer truly 'college level' curricula. Much effort is

devoted to re-teaching material students studied previously in high school.

(Confidential survey response, 2011)

In spite of the numerous responses appearing to fault the secondary curriculum, a few

respondents placed greater emphasis on students' work ethic and motivation, as opposed

to their high school preparation:

What I will rail about is the work ethic ... or lack thereof ... that we are

seeing in more and more students. One of the benefits of coming to a

small liberal arts college is the one-on-one interactions. I am not seeing enough work-ethic in students and personal responsibility. They more and more do not take advantage of this benefit of a small college. This disheartens me more than a skill deficit. We need to work on this cultural issue as an entire higher ed community. (Confidential survey response, 2011)

It's a challenge to teach mathematical thinking to those who have the intelligence but lack the motivation to do above the minimum. (Confidential survey response, 2011)

The few positive survey comments about student abilities seem to address the focus of this study directly.

I do not accept that students are incapable of learning what we are asking of them. I think that many of them have been tortured by math education most of their lives and it's difficult to change that in one semester… They've been caught in a system that teaches math very poorly with an over-reliance of memorization of algebra tricks. (Confidential survey response, 2011)

Students are more capable than some people think, if given the right inspiration and expectations. (Confidential survey response, 2011)

This concept of inspiration and expectations will be explored in greater detail with respect to the results of Phase 3 of the study.

Opinions

    Institution-specific opinions and plans. The satisfaction of mathematics departments with the quality of their service to the general education program varied widely. Although only eleven respondents indicated that the department was unhappy with the current general education program in mathematics, many more indicated plans for re-evaluation of the program, new courses, or improvements that could be made.

    Twenty-five institutions are planning specific new courses or course revisions. Of these, fifteen are specifically noted as new courses in the QL cluster, four institutions indicate plans for new or revised courses in the traditional cluster, and the remainder of planned courses or revisions are in the statistics and occupational clusters. Ninety-four institutions stated that they had no plans for new courses, and the remaining fifty-six respondents failed to respond to the question related to new courses. However, sixteen respondents (or a little less than ten percent) indicated that their colleges and universities are in the process of reviewing institutional core curricula. Most of the mathematics program chairs in this situation are awaiting more information on the new core requirements before determining the need for new general education courses, or revision to existing courses.

    A number of institutions highlighted their efforts to better serve general education students by providing additional assistance to students in core classes. This additional assistance most often takes the form of tutorial and extra study sessions staffed by faculty and mathematics majors, faculty office hours, discussion sections, and institutional academic support centers. At least one institution commented that the department makes

a deliberate attempt to have doctoral-level mathematics faculty teach general courses in order to give students the best experience possible.

However, the necessity of using part-time instructors for lower-level courses was a common lament among survey respondents. Several responses highlighted the difficulty of finding and retaining good adjunct instructors, while others noted significant differences in qualitative assessment data between sections taught by full-time versus part-time faculty. One respondent, noting a several-years-vacant tenure-track position in the mathematics department, said "the percentage of sections taught by adjuncts is shameful." (Confidential survey response, 2011)

The relationship between institutional finance and staffing, and the ability to adequately service the general education population, was a relatively common theme among survey respondents. Seventeen of the respondents cited insufficient staffing as a reason for not offering either a greater variety of general education courses, or QL courses in general. One survey comment in particular highlights the challenges and decisions facing small institutions:

> Many students would benefit from more options, like liberals arts math and quantitative reasoning. As a small university we are able to offer a very limited variety of math courses. I have mentioned the idea of quantitative reasoning to my department and members of the general education committee, but the conversation has not gone very far, mainly because other more pressing issues have demanded attention.
>
> (Confidential survey response, 2011)

The above quotation seems to highlight some ambivalence surrounding QL. The final survey question, to be explored in the next section, was designed to allow respondents to share their broader view of QL and its place in college mathematics.

General opinions. Opinions surrounding QL seem to be mixed among mathematics program chairs in small colleges and universities. While many support the purpose of teaching QL within the general education program, as in the quotation in the previous section, resource limitations seem to prevent the achievement of this ideal. A few comments were outspoken against teaching QL in the general education program, many of them in favor of a traditional curriculum including symbolic manipulation:

> All students are required to have college algebra as [a] General Education
>
> course. We feel that this is foundational mathematics. To function as
>
> parent, as employee, as productive member of society people need to have
>
> basic understanding of algebra and be able to do symbolic manipulations,
>
> graphing, use basic mathematical terminology… We feel quantitative
>
> reasoning courses do not give the students the mathematical foundation
>
> that they need. (Confidential survey response, 2011)
>
> There is nothing wrong with learning algebra and not ever "using it". It is
>
> the thought process that counts. (Confidential survey response, 2011)
>
> I believe the general population should be required to go beyond College
>
> Algebra in order to be deemed proficient in mathematics. (Confidential
>
> survey response, 2011)

Nonetheless, comments supporting quantitative literacy far outnumbered opinions either against QL or for a traditional curriculum.

> I wish more institutions would focus on quantitative literacy...I wish more emphasis was placed on non-algebraic ways of understanding our world quantitatively. (Confidential survey response, 2011)
>
> In general I think that there ought to be a larger amount of student time spent on quantitative reasoning, especially given the direction of the modern culture. (Confidential survey response, 2011)
>
> I think it's great to teach quantitative reasoning to undergraduates. The skills in problem solving are vital to many areas. (Confidential survey response, 2011)
>
> Traditional courses in mathematics generally don't work well for general education students. They have had this type of course before. It is more important to expose students to mathematics they will appreciate such as quantitative reasoning and/or statistics. (Confidential survey response, 2011)
>
> Quantitative reasoning is a weakness in society and we should expand our efforts to teach such reasoning in the general ed core. Statistical information is ubiquitous but few know how to interpret it, so intro stats is a good choice. But one course over four years of college is probably not enough. Ideally we could weave quantitative reasoning into other courses,

much like we do with writing or in some cases ethics. (Confidential survey

response, 2011)

The preceding response hints at the possibility of QL taught not only in mathematics, but

across the curriculum, an ideal that appeared in a number of other responses:

A weakness is that quantitative literacy is currently not interwoven

throughout the curriculum. We hope to correct that with our new general

education package. (Confidential survey response, 2011)

We have had some discussion of implementing a "quantitative literacy

across the curriculum" program which would likely involve implementing

QL curriculum, or assessing existing QL related curriculum, in other

courses outside the department. (Confidential survey response, 2011)

I believe whatever mathematics does, it needs to be reinforced in other

disciplines. (Confidential survey response, 2011)

[Our task] has been to convince our faculty colleagues that QL is not

strictly the purview of mathematics classes, but that we are trying to

develop quantitative reasoning skills across the curriculum. (Confidential

survey response, 2011)

A few respondents eloquently expressed their philosophy of teaching mathematics from a

perspective of QL.

Professors need to ask themselves, "Who cares? Why am I teaching this

material?" Sometimes, the answers are "No one" and "For no good

reason," so I drop them from the curriculum. In general education

mathematics courses, I like teaching topics that are interesting or beautiful
or useful. (Confidential survey response, 2011)

The way to teach the general population is to make math as interesting and
comprehensible as possible to students who aren't interested in it…This
means constantly asking students to step back and ask "what is the point of
this?" They shouldn't secretly ask that question. They should ask it
constantly. And if we can't answer it, they shouldn't have to do it.
(Confidential survey response, 2011)

Our general approach is based on our belief that the majority of students
come to us with little idea of what mathematics is in spite of having taken
math courses in most cases at least through their junior year in high
school. We try to give them a better picture. In doing so, we hope to help
think more mathematically, communicate mathematical ideas more
clearly, and in general radically revise their idea of what mathematics is.
(Confidential survey response, 2011)

The following chapter will explore case studies of several institutions that have put ideas
like those above into practice, as well as a number of institutions with a slightly different
view of QL and mathematical modeling in the general education curriculum.

Chapter 6. Narrative Case Studies

The final phase of data collection was the identification and description of courses and programs that possessed two qualities. First, based on course descriptions obtained in Phase 1, the course or program needed to show promise of the ideals presented by the CUPM (2004), including fostering student engagement and confidence with mathematics, enhancing student skills in mathematical reasoning, communication, and problem solving, and promoting critical thinking about mathematical issues arising in work and life. By virtue of this requirement, courses and programs selected for Phase 3 examination were limited to those identified within the QL cluster referenced in Appendix H.

Selection was further refined by the requirement that Phase 3 courses and programs appear sustainable, as determined by actual course enrollments in the fall semester of 2010, reported in the survey responses to Phase 2. An enrollment threshold of ten percent of the institution's full-time undergraduate enrollment was chosen, based on the assumption that a course taken by all undergraduates during a four-year program would enroll approximately one-eighth (or 12.5%) of the institution's students each semester.

Courses and programs at thirteen institutions met both of the requirements described above, and mathematics program chairs at those institutions were contacted by e-mail to request their cooperation in an in-depth telephone interview about their program. The e-mail included basic information about the study and a list of questions to be asked during the interview (Appendix F). An electronic file containing the informed

consent document (Appendix G) was attached, to be returned prior to the interview. Of

the thirteen e-mail requests, ten program chairs agreed to participate in the study (and

returned informed consent documents), one declined to participate, and two others failed

to respond to the invitation after a second request.

In-depth telephone interviews were conducted in late fall of 2011 with the ten

mathematics program chairs who had consented to participate. Upon preliminary

analysis of the interview data, it was determined that three of the courses and programs

did not meet the two criteria for inclusion in Phase 3, and that one of the interviews

concerned two separate courses of interest to the study. (In the latter case, enrollments in

the two courses were combined as a "program," and therefore met the criteria of enrolling

at least ten percent of undergraduates.) Following the interview, each respondent was

sent a draft copy of the written case study resulting from his or her interview for review,

correction, and clarification. If the respondent suggested changes, a revised draft was

also sent for approval.

Results and analysis of the Phase 3 interview data are presented in two forms. In

this chapter, the interview data has been organized into narrative case studies, to allow

the reader to place each described course into its institutional context, and judge

similarities and differences between the cases and the reader's own institution. Within

these narrative descriptions, all names of institutions and interview respondents have

been changed to protect the anonymity of the respondents. All data regarding policies

and requirements at each institution were taken from publicly available information in the

institution's catalog, and confirmed by personal communication with the mathematics

program chair. Additional information about the development process, nature, and results of specific courses and the mathematics program as a whole was obtained by personal communication with the mathematics program chair. The same interview data has been subjected to more structured analysis in Chapter 7, which examines the data collected in Phase 3 from a variable-oriented perspective.

During interactions with the institutions profiled in the remainder of this chapter, the terms "success" and "successful" were used often by the mathematics program chairs being interviewed. For example, many of them referenced "student success rates" or "successful courses" based on criteria used by the institution or department. Although a few institutions mentioned using the quantitative literacy rubric developed by the American Association of Colleges and Universities (AAC&U, 2010) to provide external validation of their courses, most rely on internal (and often informal) evaluations of success.

Consequently, the use of the words "success" and "successful" in these case study descriptions should be interpreted from an institutional perspective, and not in the context of the CUPM recommendations. In the concluding paragraphs of each description, where the researcher connects the institution's program with the CUPM guidelines, the close proximity of references to "success" and the CUPM recommendations should clarify that those specific instances revert to the operational definition of success used in the study, rather than internal definitions of success used by institutions.

Artis University: Mathematics and Philosophy

Artis University is a coeducational liberal arts university in the Western region of the United States. Its undergraduate enrollment in the fall of 2009 was in the middle 50% of all the schools in the study, with approximately 60% of undergraduates living on campus. Admission to the university is competitive, but no information is available regarding the percent of first-year students in the top decile of their high school class. During the 2008-09 academic year, the institution operated at a modest surplus, but its endowment balance at the end of the same year was one of the lowest of all institutions in the study group (AFT, n.d.; Barron's, 2010; College Board, 2010a).

Academically, the university requires all students to take a common core mathematics course, entitled Nature of Mathematics, during their first semester of enrollment. This course is linked to the Introduction to Philosophy course contained in the institution's core curriculum, and students progress through the two courses as a cohort. The Nature of Mathematics emphasizes systematic inquiry and clear communication in accordance with the university's core curriculum goals. Students are expected to gain an understanding of "traditions, leaders, basic facts and procedures useful in mathematical investigation … learn necessary facts and information within certain mathematical areas … [and] investigate, formulate and solve scientific problems" (Nature of Mathematics syllabus, 2011, pp. 2-3), as well as to develop both written and oral communication skills related to scientific arguments (W. P. Thompson, personal communication, 11/18/11). Students are required not only to complete homework, tests, and quizzes, but are assigned extensive supplementary readings and written work, and

must complete a major mathematical research project and presentation on a topic of their own choosing.

The course was begun in 2005 as a component of the university's general education program. Dissatisfied with existing college algebra and precalculus courses, the mathematics department chose to focus the course on critical thinking and making students aware of mathematics in the world. The course gives students a broad look at various fields of mathematics not normally taught in high school, and promotes student engagement and interest through hands-on activities and explicit connections to real life. According to the mathematics program chair, one of the greatest implementation issues was in organizing the course content around interesting mathematical topics that were also accessible to average students (W. P. Thompson, personal communication, 11/18/11). Some faculty outside the mathematics department were initially concerned that the course was inappropriate for general education, but support from the institution's administration was strong, and the mathematics faculty have since added multiple reading and writing assignments to the course. This has allowed the general faculty to see the value of the approach to QL taken in the Nature of Mathematics.

The mathematics faculty at Artis continually gather data to assess the success of the course. The program chair states that the greatest ongoing challenge in teaching the course is working with students who were unsuccessful in high school mathematics "to open their minds toward other understandings [of mathematics]" (W. P. Thompson, personal communication, 11/18/11). In order to help these students, the department has instituted regular peer tutoring and "math lab" assistance programs. Nonetheless, the

program chair admits that the distribution of grades for students enrolled in the course "seems low." In general, he states that student evaluation comments indicate frustration over students' perceived lack of personal quantitative skills, but also appreciation that the course attempts to challenge students in mathematical topics that go beyond those contained in traditional mathematics courses. A small number of students have used their work in the course in the university's showcase of undergraduate research, and a few students have chosen to major or minor in mathematics following their experience in the course. As the coupling of the Nature of Mathematics course with the Introduction to Philosophy course was instituted only recently (in the fall semester of 2011), it is too early to judge the effectiveness of the linked courses, and the mathematics program chair is unsure whether the interdisciplinary connections will be temporary or will have lasting impact on students' thought (W. P. Thompson, personal communication, 11/18/11).

The Nature of Mathematics course at Artis University is a promising program, particularly in its explicit connection to the philosophy core course at the institution, and in its extensive reading and writing requirements. These two features alone are likely to enhance students' mathematical communication skills and promote critical thinking about quantitative matters arising in life. Although the mathematics department has struggled to build students' confidence in their mathematical abilities, the student comments referenced above seem to make it clear that students are actively engaging in the course material. In summary, this course seems consistent with the standards set forth by the Mathematical Association of America (CUPM, 2004).

Magistra University: College Mathematics

Magistra University is a coeducational liberal arts college in the Great Lakes region of the United States. Its undergraduate enrollment in the fall of 2009 was in the middle 50% of all the schools in the study, with approximately 56% of undergraduates living on campus. Admission to the university is competitive, but no information is available regarding the percent of first-year students in the top decile of their high school class. During the 2008-09 academic year, the institution operated at a modest surplus, but its endowment balance at the end of the same year was one of the lowest of all institutions in the study group (AFT, n.d.; Barron's, 2010; College Board, 2010a).

Academically, the university requires all students to demonstrate minimum competency in mathematics at a level beyond elementary algebra. This competency may be demonstrated by CLEP or AP scores, or by satisfactory completion of one of several mathematics courses. The mathematics department views the study of mathematics systemically, with a three-course sequence in pre-algebra, algebra, and college mathematics considered the core of their general education program (M. J. Davis, personal communication, 12/28/2011). The course of particular interest to this study is entitled College Mathematics, which includes topics and applications in algebra, probability, statistics, and financial mathematics.

The course was developed approximately ten to fifteen years ago, in response to growing concern about extremely low success rates in the class that was then in place as the institution's quantitative core requirement. Prior to the establishment of the College Mathematics course, many faculty outside the mathematics department harbored open

hostility toward the university's quantitative core, believing that the study of mathematics at the institution was unnecessarily rigorous (M. J. Davis, personal communication, 12/5/2011). Following a university-wide needs assessment, College Mathematics was designed as a course that would promote student success in mathematics, while being relevant to students' lives and work.

As it is currently taught, College Mathematics ensures consistency between sections using common quizzes and exams for student assessment. Homework and quizzes use an online system wherein students may attempt assessments multiple times in order to succeed, and in fact students are required to achieve a score of 80% on each homework assignment in order to access online quizzes. In addition to encouraging student persistence, this mastery approach promotes student success on later exams covering the same topics. Most instructors of the course, however, supplement required assessment elements of the course with additional homework, collaborative group assignments, and projects (M. J. Davis, personal communication, 12/28/2011).

Several challenges arose during implementation of the College Mathematics course at Magistra. The first was appropriate placement of students into the course. All entering students take a math placement examination that determines the appropriate initial mathematics course. In the early years of the course, waivers of placement by instructors resulted in wide-ranging skill levels within the class, and a number of students proved unprepared with respect to the mathematical skills required to succeed in the course. Placement standards are now rigorously applied, and no instructor waivers are given (M. J. Davis, personal communication, 12/5/2011). The other challenge has been

quality control between sections, given the frequent use of adjunct instructors in teaching the College Mathematics course. This has largely been resolved by enforcing measures requiring all instructors to teach to a common standard. Such measures include the use of common syllabi, common homework assignments, and uniform mid-term and end-of-course examinations.

The mathematics department at Magistra has been diligent about evaluating student success in the course using several measures. The first are the completion and passing rates for students; approximately ninety percent of students enrolling in the course complete it with a passing grade. Evaluations of student satisfaction, completed each semester as a comparative measure of instructor quality, are generally positive. Finally, the instructors of the course meet at least once each semester to discuss successes and challenges that have arisen in the course, and possible approaches for course revision. The mathematics program chair also notes that feedback from other disciplines indicates that students completing the course encounter greater success in subsequent courses in statistics and research methods (M. J. Davis, personal communication, 12/5/2011).

The high completion rate appears to indicate that the College Mathematics course at Magistra encourages student persistence, and may foster student engagement and confidence in mathematics. While the course enrollment is substantial (enrolling approximately 14% of Magistra's undergraduate population in the fall semester of 2010), the objectives listed in the course syllabus are largely focused on skills, with little reference to mathematical reasoning, communication, and problem solving. However,

the mathematics program chair asserts that these elements are indeed central to the course, as are questions of wisdom, ethics, and social responsibility. Students are asked to not only apply algorithms, but to evaluate problem-solving strategies and approaches in the context of class discussions and projects. In the words of the mathematics program chair, students in the course are expected "to internalize the understanding that mathematics and its applications have relevance to one's values, ethics, and the way in which one interacts with the world" (M. J. Davis, personal communication, 12/28/2011). Given this emphasis, the College Mathematics course appears highly consistent with the goals set forth by the Mathematical Association of America (CUPM, 2004).

Scientia University: Social Issues in College Algebra

Scientia University is a coeducational liberal arts college in the Plains region of the United States. Its undergraduate enrollment in the fall of 2009 was in the lowest quartile of all the schools in the study. Admission to the university is competitive, and approximately 7% of first-year students were in the top decile of their high school class. During the 2008-09 academic year, the institution operated at a surplus, with a relatively high endowment balance at the end of the same year (AFT, n.d.; Barron's, 2010; College Board, 2010a).

Academically, the university requires all students to complete one general education course in Quantitative Reasoning, selected from a list of four courses. In addition, the university requires all students to take six common core courses, one of which introduces reasoning, logic, and axiomatic systems in the context of trials throughout history. Although the topics included in this interdisciplinary core course

may be considered elements of QL, the course is not "mathematical" in nature and will not be discussed in detail in this paper.

Two of the four courses acceptable for general education credit at Scientia are of particular relevance to the topic of this study. The first, a course entitled Mathematics for the Liberal Arts, considers mathematics in the context of practical applications including management science, statistics, probability, and financial mathematics. In addition to completing homework and tests, students in the class are expected to make in-class presentations on quantitative articles from the popular press, and are encouraged to work in groups on projects related to the course material.

The other Scientia course of interest to this study is College Algebra. While the course name is traditional, the approach taken to the course is unusual. As we will see at several institutions profiled in these case studies, the course takes a data-based modeling approach to college algebra, but places mathematical concepts in the context of social, economic, and political concerns such as hunger, poverty, and environmental issues. The current course began in 2003, in recognition that Scientia's students were not well-served by a traditional college algebra course (K. E. White, personal communication 12/14/2011). The course's development, along with the writing of a new "learner-centered, inquiry-intensive, data driven, activity-oriented" text, was supported by a grant from the National Science Foundation (NSF). The primary text for the course was developed by the mathematics program chair over several years, and emphasizes reading and projects over routine mathematical exercises. These projects are used extensively

throughout the course, as students are expected to work collaboratively both inside and outside of class.

The NSF support for this project's development provides a wealth of assessment data on the success of the redesigned course. In evaluations, students cited the course structure, particularly the regular use of collaborative groups, as a significant factor in helping them to learn mathematics, in comparison to previously-taken courses. Although there is no data available for comparison of student attitudes in the reform ("social issues") sections with traditionally-taught sections, the mathematics program chair remarks that the new experience of reading in math and the deliberate ambiguity of many activities in modeling real-world situations produced some negative reactions from students early in the semester. He also notes that most students seemed to overcome this in the first few weeks (K. E. White, personal communication 12/14/2011).

The project has also examined numeric data comparing reform and non-reform sections of college algebra. In comparison of common skills-based final exam questions, students taught under both approaches showed approximately the same level of mastery, in spite of the expectation that students in reform sections would perform slightly worse than students in traditional sections. However, students in reform sections showed both higher completion rates for the course, and a higher percentage of overall course grades in the A and B range. The program chair hypothesizes that these results are indicative of increased student confidence under the reform approach (K. E. White, personal communication 12/14/2011).

In summary, the focus on data and social issues in Scientia's College Algebra course, coupled with its learner-centered emphasis, serves to improve student confidence with mathematics and requires students to think critically about quantitative issues on a global scale. The extensive use of collaborative groups promotes mathematical communication, and the ambiguity of the real-life situations encountered within projects and activities requires students to become active problem solvers. By the standards of this study and the recommendations of the CUPM (2004), this program could be considered a success.

Sumus College: Problem Solving and Modeling, Two Courses

Sumus College is a coeducational liberal arts college in the Plains region of the United States. Its undergraduate enrollment in the fall of 2009 was in the middle 50% of all the schools in the study, with approximately 75% of undergraduates living on campus. Admission to the college is competitive, and approximately 13% of first-year students were in the top decile of their high school class. During the 2008-09 academic year, the institution operated at a deficit, but its endowment balance at the end of the same year was in the highest quartile of the study group (AFT, n.d.; Barron's, 2010; College Board, 2010a).

Academically, the college requires all students to demonstrate minimum competency in mathematics at the level of elementary algebra. This competency may be demonstrated by an entering student's ACT or SAT score, or by satisfactory completion of a course offered by the college's learning center. In addition, each student must complete one general education course in Mathematical Reasoning, selected from a list of

five possible courses. As of this writing, the mathematics department does not offer a statistics course for general education students, but plans to offer such a course in the near future.

Two of the five courses acceptable for general education credit are of particular relevance to the topic of this study. The first is a course entitled Problem Solving, designed to "give students a firm problem-solving foundation." Throughout the semester, students work to develop a set of twelve problem solving strategies, based on the work of George Pólya (1945) and on a text written specifically for the course by the college's mathematics faculty. Students are expected to communicate mathematics regularly, both orally in the form of in-class problem presentations, and in writing through homework assignments and journaling. The course syllabus explicitly encourages students to work collaboratively in groups outside of class on problem-solving assignments.

The Problem Solving course was started approximately four years ago, in response to a sense in the mathematics department that students had little understanding of the process and strategies for solving quantitative problems. In early offerings, students resisted the need for independent thinking inherent in the design of the course, expecting to be spoon-fed information, but word-of-mouth regarding course culture and expectations seems to have alleviated some of this resistance. The writing component of the course continues to draw mild objections from some students (M. Y. Moore, personal communication, 11/28/2011).

Most disciplines beyond mathematics have reacted positively to the new course after seeing improvement in students' general problem solving skills, as well as in their level of persistence in solving problems. More objectively, the college's education department has noted higher mathematics scores on standardized teacher certification tests among students who have taken the Problem Solving course. In general, the course has gained broad institutional acceptance, and has become the mathematics course that most advisors recommend to their students (M. Y. Moore, personal communication, 11/28/2011).

Building on the success of the Problem Solving course, another course in the program, Modeling and Applications, resulted from a redesign of a traditional College Algebra course approximately three years ago. Combining algebra and spreadsheet technology, students explore applications of concepts ranging from linear models through logarithmic and cubic functions. The course emphasizes the use of real-world data in mathematical problem solving, and encourages students to work collaboratively on assignments. The focus of the course is on enabling students to "read, interpret and analyze problems; and gain quantitative literacy and confidence" (Sumus College catalog, 2010).

There was some institutional resistance to the renaming of College Algebra, largely due to the perceived impact on the post-baccalaureate admissions process of the college's graduates. Among the faculty in the sciences and the college's administration, there was concern that graduate admissions officers would fail to recognize "Modeling and Applications" as equivalent to "College Algebra" on an undergraduate transcript. As

of yet, there has been no feedback with regard to the course-naming issue in relation to the post-baccalaureate admissions process. According to the mathematics department chair, students' experience in the new course has been largely positive, particularly with respect to the extensive use of technology for modeling and graphing real-life data (M. Y. Moore, personal communication, 11/28/2011).

Both courses are taught exclusively by full-time faculty members. The mathematics faculty feel that the extensive preparation time and unique approach used make these courses inappropriate as a teaching assignment for adjunct faculty. In combination, the two courses have been embraced by the college faculty as a whole, with the result that one department beyond mathematics is considering a new minor program that would be centered around both courses.

Sumus College has taken a two-fold approach to quantitative literacy, providing alternatives from which students may choose depending on their needs. Although either course may be used as a prerequisite for the college's Precalculus course, the Modeling & Applications course is more likely than the Problem Solving course to be taken by students desiring further study in mathematics. While serving as a terminal mathematics course for some students, the Problem Solving course also functions as a prerequisite course for Sumus's sequence in mathematics for prospective elementary school teachers. In the fall semester of the 2010-11 academic year, the combined enrollment for both courses was approximately ten percent of the college's total undergraduate enrollment.

The mathematics department chair at Sumus asserts that these two courses have increased student engagement in mathematics and that, in addition to improving student

persistence in problem solving, have made students more confident in their own quantitative abilities (M. Y. Moore, personal communication, 11/28/2011). As described above in relation to standardized teacher certification tests, there is some conjecture that students' mathematical reasoning skills are enhanced by at least one of the two courses, although no formal attempt has been made to study a possible relationship between successful completion of the Problem Solving course and subsequent teacher certification test scores. Both courses, with their emphasis on collaboration between students in problem solving activities, are likely to promote the development of mathematical communication, as is the prominence of writing within the Problem Solving course. All of these features combine to illustrate two courses designed in the spirit of the MAA/CUPM recommendations (CUPM, 2004).

With regard to servicing the major along with general education courses, Sumus is unusual among small colleges in two respects. The college has a relatively large number of math majors, approximately five percent of the institution's total undergraduate population, resulting in an ability to draw sufficient enrollment in upper-level courses to offer most courses required by the major at least once per year. Some elective upper-level courses are offered in a two-year rotation. With the frequency of upper-level offerings, Sumus still faces the challenge of staffing those sections, to the extent that full-time mathematics faculty members regularly teach an overload of one section per year. As a rule, Sumus does not rely on adjuncts to teach any of their mathematics courses.

Natura College: Quantitative Reasoning Core

Natura College is a coeducational liberal arts college in the Great Lakes region of the United States. Its undergraduate enrollment in the fall of 2009 was in the middle 50% of all the schools in the study, with approximately 69% of undergraduates living on campus. Admission to the college is competitive, and 23% of first-year students were in the top decile of their high school class. During the 2008-09 academic year, the institution operated at a deficit, but its endowment balance at the end of the same year was in the top quartile of all institutions in the study group (AFT, n.d.; Barron's, 2010; College Board, 2010a).

The college requires all students to take a common core of courses, including one entitled Quantitative Reasoning, in which students are "introduced to quantitative approaches and mathematical tools for understanding the world, thinking critically about quantitative and logical information, and for making informed decisions about issues in everyday life" (Natura College catalog, 2010). In an exception from the liberal arts core requirement, students are exempt from taking this specific course if their program of study requires a course in calculus or discrete mathematics, and it has been proposed that students taking the college's introduction to computing course be afforded the same exemption (C. J. Johnson, personal communication, 12/15/2011).

The liberal arts curriculum at Natura College was modified in the 2007-08 academic year, resulting in the revision of the previous general education mathematics course. This revision incorporated Natura's liberal arts focus on "understanding the world" by including representation and interpretation of data, probability and statistics,

growth models, personal finance, and applications of mathematics beyond business and natural science. Further, the course emphasizes the development of problem-solving skills, mathematical communication, working in group settings, the use of spreadsheet software, reflection on learning, and experiential learning through projects and lab exercises.

Although the non-mathematics faculty at Natura strongly support the need for a quantitative course within the liberal arts core, there was some initial resistance during the development of the Quantitative Reasoning course. After the structure and goals of the redesigned course were formalized into student learning outcomes (SLOs), the faculty body responsible for approving new courses at the institution required that the mathematics department also provide assessment rubrics for each SLO. Since this mandate occurred prior to the development of specific projects, assignments, and classroom activities for the new course, the resulting SLO assessment rubrics are in a generalized form that may not translate well to specific assignments. One factor that aided the mathematics faculty in working within the required SLO structure is that the mathematics faculty at Natura have been historically well-represented within campus leadership positions, as well as in the development of the new liberal arts core as a whole (C. J. Johnson, personal communication, 12/15/2011).

Since the inception of the new course approximately three years ago, there have been small modifications in the types and structure of assignments, but the most significant experiment with the course has been the recent linking of a section of Quantitative Reasoning with a section of the English course contained in Natura's liberal

arts core. This model, designed to reflect the interdisciplinary philosophy of the core, enrolled a common cohort of students in the two sections so that the English and mathematics instructors could purposefully develop common themes that would explicitly highlight connections for students.

The greatest challenges faced by the mathematics faculty in teaching the Quantitative Reasoning course have surrounded both the level of mathematical knowledge of enrolled students, and their attitudes toward mathematics. The exemption from the courses for students taking calculus or discrete mathematics as part of their major program effectively removes the most mathematically-capable students from the audience for this course, leaving many students with comparatively low quantitative skills who often enter the course with negative attitudes toward mathematics. In the opinion of the mathematics program chair, this population of students expects and is comfortable with traditional pedagogies (often in spite of previous patterns of failure under traditional models). Because Quantitative Reasoning is taught from a student-centered perspective that requires active learning and participation, the mathematics faculty have encountered strong resistance from students regarding the course expectations. He hypothesizes that students' psychological basis for this resistance is a fear of damaging feelings of self-worth; students may feel safer in not putting forth effort in the class, so that they can blame possible failure on the extrinsic factor of "not trying." This lack of student effort has created frustration among the instructors of the course, and the mathematics program chair notes that the department may need to examine "alternative instructional models" (C. J. Johnson, personal communication, 12/15/2011).

Informally, the mathematics department has not noted any improvement in student behaviors over the previous liberal arts core course, although the program chair suggests that there may be some progress toward improved student attitudes toward QL, in spite of the difficulties noted above. Now that the course has been in place for three years, the department is beginning efforts to formally assess the success of the course with respect to the quantitative outcomes in Natura's liberal arts core, using the internally-developed rubrics mentioned earlier.

The intended curriculum of the Quantitative Reasoning course at Natura College appears to incorporate many of the ideals set forth by the Mathematical Association of America (CUPM, 2004). It aims to enhance student skills in mathematical reasoning, communication, and problem solving, and incorporates real-world quantitative topics. The pedagogical design of the course should foster student engagement and confidence, and it is unclear why the course seems to be failing in this respect. Further investigation (beyond the scope of this study) with respect to student engagement and confidence may be appropriate before the mathematics department considers major changes to the course structure.

Petimus College: Modeling with Quantitative Information

Petimus College is a coeducational liberal arts college in the Southeast region of the United States. Its undergraduate enrollment in the fall of 2009 was in the upper quartile of all the schools in the study, with approximately 43% of undergraduates living on campus. Barron's (2010) classifies admission to the college as competitive (Barron's, 2010), but the mathematics program chair notes that the college's admissions policy is

noncompetitive. No data is available on the percentage of entering students who were in the top decile of their high school class. During the 2008-09 academic year, the institution operated at a deficit, with a low endowment balance at the end of the same year, placing it in the lowest quartile of the institutions in the study for both financial measures (AFT, n.d.; Barron's, 2010; College Board, 2010a).

Academically, the college requires all students to complete one general education course in Mathematics, selected from a list of five possible courses. The course of particular interest to this study, entitled "Modeling with Quantitative Information (MQI)," integrates mathematics and technology to develop students' abilities to apply and integrate knowledge in quantitative situations. In this freshman level course, students explore geographical information systems, density plots, discriminant analysis and contour plots, time series, dynamical systems, and linear modeling, using a textbook written by the mathematics program chair explicitly for the course. Students are assessed through the use of guided modeling projects, reading and writing assignments, regular homework, and exams.

The MQI course gradually developed over a long period of time, after the mathematics faculty noted that students in courses in the traditional GATC sequence had a high failure rate and difficulty transferring quantitative skills to further coursework or real-life applications. The department attempted to institute several computer-assisted programs in traditional courses, and experimented with offering a course in quantitative topics which, according to the program chair, was lacking in focus. This topics course, under the chair's direction, took on a data-based approach and was offered occasionally

for several years. Approximately three years ago, the department officially created MQI as their lowest-level (and most commonly-taken) general education offering, when the college administration offered to give the department a new faculty position in order to effect the change (G. H. Thomas, personal communication, 11/29/2011).

Two members of the mathematics faculty initially opposed the change, expressing preference for a traditional curriculum. Of the two, one now supports the course, but would appreciate the creation of additional ancillary materials to support instruction. Another member of the mathematics faculty has taken the lead in implementation of the course and coordination of the multiple sections and instructors, holding weekly meetings and developing common assessments. However, the program chair notes that instructor training has been relatively weak, especially in light of the fact that nine different instructors have taught the course in the past three years. The chair, who is also the course designer, continually consults with disciplines beyond mathematics to see how the course could be improved, and the typical response is to "keep doing what you're doing" (G. H. Thomas, personal communication, 11/29/2011).

The program chair notes that, coupled with several changes in Petimus' developmental mathematics program, the MQI course provides students with a dramatically increased success rate in satisfying the general education mathematics requirement. Failure rates were high in developmental courses that served as prerequisites for Petmius' general education courses in mathematics, and in the general education course that existed previous to MQI. Consequently, the proportion of students receiving general education credit after taking two semesters of mathematics was

approximately fifteen percent. In the MQI course, the chair estimates the success rate at

55-60% for first-time enrollees (G. H. Thomas, personal communication, 11/29/2011).

In addition to improved passing rates, the chair notes that some students in the

MQI course are thinking more deeply about mathematics than students in earlier, more

traditional courses. In fact, in the opinion of the chair, students in this general education

course are doing real-life mathematical work that challenges some mathematics majors in

tutoring settings, and even some member of the mathematics faculty at times (G. H.

Thomas, personal communication, 11/29/2011). As a result of this opinion, the

department has begun efforts to increase the level of QL in the courses taken by

mathematics majors, with a specific focus on increasing expectations regarding writing

and technology use.

The approach taken by the MQI course reflects the philosophy of the program

chair that QL is about problem solving with real-life quantitative information, and not

about teaching specific methods for solving unrealistic artificial problems. For general

education students, he objects to standard college algebra courses, echoing the sentiments

of Don Small (2006), on the grounds that only a small percentage of students need the

algorithmic skills long considered part of the "traditional" curriculum.

The MQI course at Petimus College can be considered successful in a number of

respects, in relation to the CUPM recommendations. According to the program chair, the

course has increased student engagement and critical thinking about quantitative problem

solving. Throughout the course, students are expected to communicate their reasoning

about real-world issues. In the case of this particular course, the mathematical topics

addressed display a high degree of variety, novelty, and depth as compared to applications often covered in a function-oriented modeling course. Finally, reported course enrollments of approximately 18% of the full-time undergraduate population at the college in Fall, 2010, reflect the strong commitment that Petimus has made to the success of the course.

Verum University: Great Ideas Core

Verum University is a coeducational liberal arts university in the Southeast region of the United States. Its undergraduate enrollment in the fall of 2009 was in the middle 50% of all the schools in the study, with approximately 61% of undergraduates living on campus. Admission to the college is classified as very competitive (Barron's, 2010), and 24% of first-year students were in the top decile of their high school class. During the 2008-09 academic year, the institution operated at a modest deficit and had a relatively low endowment balance at the end of the same year, placing it in the second-lowest quartile of all institutions in the study group on both financial measures (AFT, n.d.; Barron's, 2010; College Board, 2010a).

The college requires all students to take a common core of courses, one of which is entitled Great Ideas of Modern Mathematics, that "explores major modern mathematical developments and helps students to understand and appreciate the unique approach to knowledge employed by mathematics" (Verum University catalog, 2010, p. 136). Favoring depth of coverage over breadth, each section of the course addresses three mathematical topics from the modern era (i.e., post-Isaac Newton). All students at

the university are required to take this core course at some point during their undergraduate years (L. W. Jackson, personal communication, 12/16/2011).

The current core curriculum at Verum, "aimed at providing a common learning experience for all students" (Verum University catalog, 2010, p. 134), was developed in the 1990s, with support from a grant provided by the National Endowment for the Humanities. In addition to providing support for the development of the core curriculum, this grant also helped to create an endowment specifically to support the continuation of Verum's core curriculum, guaranteeing the availability of future resources. However, the initial guidelines for the Great Ideas course provided instructors with a great deal of latitude in selecting the three specific topics to be included, and the mathematics department concluded that the course was not providing the common learning experience mandated by the core curriculum guidelines. Consequently, the department modified the course guidelines several years ago to include probability and logic in all sections of the course, with the third topic left to the discretion of the instructor. The mathematics program chair and department faculty review the common topics and textbook for appropriateness approximately every two years (L. W. Jackson, personal communication, 12/16/2011).

The syllabus for the Great Ideas course emphasizes not only mathematical correctness, but creation and communication of "good mathematics." Students are required to write a mathematical autobiography, reflecting on their own mathematical experiences. In the past, students were also required to write papers about mathematics, but this requirement has been abandoned due to the low quality of student work.

The department has been conscientious in assessing the effectiveness of the Great Ideas course, both within and between individual sections of the course. Within each section, pre- and post-testing is conducted to determine the change in student knowledge for the two common topics (probability and logic), and the analysis has shown statistically significant increases in student understanding of these two topics. Each semester, the department mandates that a common question be included within an assessment of the instructor's choice, in order to ascertain the development of mathematical skills for students across sections of the course. This commonality provides a basis for the department to review the effectiveness of the course as a basis for future improvement (L. W. Jackson, personal communication, 12/16/2011).

Some of the challenges faced in the development and continuation of the Great Ideas course are typical for courses of this nature. The student audience for the course varies widely, with many students delaying the course until late in their program of studies. This results in sections that have large numbers of graduating seniors (as many as 20% of a section's enrollment), resulting in generally high student anxiety levels within classes.

Staffing is another common concern. In the opinion of the mathematics program chair, the philosophical approach used in teaching the Great Ideas course makes it inappropriate for adjunct or part-time instructors. Consequently, the course is only taught by full-time faculty at the university, who willingly accept the staffing burden because of their conviction that the course accomplishes the goals of the university's core curriculum. In a related issue, the enrollment cap for sections of the Great Ideas course

has historically been higher than that of other courses in the university's core curriculum, on the grounds that other courses in the core required more writing, and therefore more time by the instructor. However, the university has recently approved a common cap for all core courses, which may relieve some of the burden on the mathematics faculty (L. W. Jackson, personal communication, 12/16/2011).

The mathematics department at Verum continues to focus on the quality of the student experience, particularly within the courses offered for the mathematics major. While most upper-level courses are offered on an alternate-year rotation, a recent modification to the major program has been to offer a transition course in proof and logic each fall, in order to provide a common foundation for more advanced courses. The department is also developing a senior-level capstone course that will encourage students majoring in mathematics to construct a broad view of the interconnectedness of mathematics as a whole.

In summary, the Great Ideas of Modern Mathematics course at Verum University seems to approach the ideals set forth by the Mathematical Association of America (CUPM, 2004) for developing quantitative literacy. It emphasizes communication and reasoning, and focuses on depth of understanding. This depth, in turn, is likely to foster student engagement and curiosity about mathematics. Even in its major program, the mathematics department at Verum seems focused on providing all students with an experience that will encourage students "to understand and appreciate the unique approach to knowledge employed by mathematics" (Verum University catalog, 2010, p. 136).

Some features are common to many of the courses described in this chapter. As courses were selected for their apparent consistency with CUPM recommendations, most of the courses profiled require students to demonstrate critical thinking and problem solving skills in the context of quantitative situations arising in the real world. All contain elements of mathematical communication; although in many of the courses this takes the form of writing and oral presentation, some require extensive reading as well. Without exception, the courses described use multiple modes of assessment, often including projects, writing assignments, and collaborative activities along with traditional tests, quizzes, and homework. A few of the courses explicitly promote an inquiry approach to learning, expecting students to develop mathematical ideas through hands-on activities. On the negative side, nearly all of the mathematics program chairs interviewed note low student confidence and ability as significant hurdles in teaching their institution's QL course. While some departments have made the deliberate decision to staff QL courses exclusively with full-time faculty, those using adjuncts cite variation in teaching philosophies among instructors of the course as another challenge in providing consistent quality between sections.

The seven narrative descriptions contained in this chapter have provided the reader with rich, context-based descriptions of eight very different courses of interest to this research. In the following chapter, we use these descriptions, along with additional data gathered throughout the study, to analyze these courses in terms of variables that may have the potential to strengthen QL courses offered at small institutions.

Chapter 7. Analysis of Case Studies

In this chapter, we examine the reasons for and extent of the success of the courses and programs described in Chapter 6 as a group. While the case studies in the previous chapter took a narrative viewpoint, this chapter summarizes and analyzes the case study information from a discrete, variable-oriented perspective.

Factors in Program Design.

Throughout the collection of data in the final phase of this study, and the preparation of the case studies in the previous chapter, a number of variables began to emerge as possible factors in the design of effective programs or courses in QL at small institutions. Some of these variables are related to the operations of specific courses or programs, while others address departmental and institutional philosophies and attitudes related to teaching QL to the general population of undergraduates. Although these variables will be examined in greater detail later in this chapter, a brief summary is provided in the paragraphs that follow.

Variables classified as operational include those associated with the day-to-day pedagogical practices inherent in the course, as well as with the institutional framework for and history of the course. These operational variables are:

- Course maturity – the length of time the course has existed in its present form
- Textbook – the nature of the textbook and other print and electronic materials used to support instruction
- Assessment – the practices used within the course for assessment of student learning

- Internal success – the combination of quantitative and qualitative measures used by the institution in determining whether the course is "successful"

- Faculty effort – the level of effort required of departmental faculty in order to support student learning in the course

- Enrollment – the Fall, 2010, enrollment in the course as a percent of the institution's full-time undergraduate enrollment

- Required in core? – the degree to which a course is required in the core curriculum applicable to all undergraduates at an institution

    Philosophical variables include those variables that, while not directly related to current course operations, reflect departmental and institutional attitudes surrounding the teaching of QL, along with a course's degree of conformance with the recommendations of the MAA/CUPM. The philosophical variables that became evident during the study are:

- Departmental support – the level of support provided for the course within the mathematics department

- Institutional support – the level of support provided for the course beyond the mathematics department

- Motivation – the reasons for creation or modification of the course into its current format

These ten variables will form the core of discussion and analysis of the primary findings of this study. Table 9 summarizes the following discussion and analysis of these variables for each of the courses referenced in the case studies of Chapter 6.

The primary variable of interest to this study is the degree to which a course adheres to or appears to promote the values outlined in the CUPM Curriculum Guide (CUPM, 2004). These guidelines, described at several points throughout this study, emphasize that effective QL programs should

- Foster student confidence and engagement in mathematics;

- Enhance students' skills in quantitative reasoning, communication, and problem solving; and

- Promote critical thinking about mathematical issues arising in work and life.

Following completion of data collection and preliminary narrative analysis, the eight courses described in the case studies were classified as to their degree of consistency with the CUPM recommendations. In a quantitative study, the variable of CUPM consistency would be considered the resultant or dependent variable, since it is the major focus of this study. Courses possessing all or nearly all of the characteristics outlined above were noted as carrying a "high" degree of CUPM consistency, while those that appeared to lack some aspect of the guidelines received a "moderate" classification on this variable. It should be noted that the courses and programs profiled earlier were selected on the basis of their potential for realizing the CUPM ideals. Therefore, it is not surprising that all eight courses profiled were rated as having a high or moderate degree of consistency with the CUPM guidelines.

Operational Variables

Within the operational variable of course maturity, or the length of time the course has existed <u>in its present form</u>, two subsets appeared within the course profiles.

Five of the eight courses have been in existence for a period of two to four academic years, and were classified as "new" (with only one course under three years old). The remaining three courses have histories ranging from seven to fifteen years, and were classified as "mature." There is no apparent relationship between course maturity and the degree to which a course is consistent with the recommendations of the CUPM.

Two points that should be noted in relation to course maturity, however, are the timing of the contemporary QL movement and natural institutional planning cycles. Recall that contemporary theories surrounding QL began to arise in the early 1990s, rendering it unlikely that a course developed before that time would satisfy the goals outlined by the CUPM. It is reasonable to expect that courses incorporating the spirit of QL education have been developed since the mid-1990s, and will therefore be no more than eighteen years old. A second factor contributing to (or inhibiting) course maturity is regular institutional review of core undergraduate curricula. Two of the five "new" courses were motivated in part by significant revisions in their college's core curricula. Although the frequency of this type of broad review varies by institution, such a review may spur creation of new courses or substantial revision of existing courses.

All of the courses profiled use textbooks to support student learning. Examination of syllabi permitted identification of the specific textbook in use for each course, and the commercial textbooks used were then examined and classified as "reform" or "traditional," depending on the degree to which they appeared to support QL education. Of the eight courses, four use textbooks classified as "reform," while one uses a "traditional" textbook. The surprise in textbook identification, however, was that three

of the eight courses are using textbooks that were written specifically for the course at the particular institution. In all three cases, labeled "custom," the text materials were created through the active involvement of the mathematics faculty at the institution, on their own initiative. There does appear to be a relationship between the type of text used and the CUPM consistency. All three courses using "custom" texts show a "high" degree of CUPM consistency, while of the five courses using commercial texts, only one shows "high" adherence to the CPUM guidelines. The other four display only "moderate" CUPM consistency.

The third operational variable relates to the type of assessment practices used in the course. Without prescribing specific assessment practices contributing to QL in the undergraduate population, CUPM guidelines emphasize written and oral communication, the practice of a variety of problem-solving strategies in real-world contexts, and conceptual understanding as opposed to algorithmic proficiency (CUPM, 2004, pp. 28-30). Courses appearing to incorporate all of these elements into their assessment practices were classified as having "strong" assessment practices, while courses missing one of the above factors were classified as using "moderate" strategies. Only one course seemed to be missing two elements, and received a "weak" assessment rating. (There may be a relationship between assessment practices and textbook selection, since the course receiving a "weak" assessment rating was also the only one using a "traditional" textbook.) It is difficult to isolate operational assessment practices from the variable of CUPM consistency, since course objectives are often reflected in student assessment.

Therefore, hypothesizing on any further relationship between these two variables would be unwise.

Each institution uses its own measures to determine whether a given course is successful. Some colleges and universities base judgments of success on the percent of students who successfully complete a course. Others use a system of end-of-term student evaluations to gauge student satisfaction. Many institutions use a combination of these measures, along with less formal evaluation by faculty and students to determine whether a course is a success. This collection of internal evidence, as reported by the mathematics program chair at each institution, forms the basis for assigning a success rating to each course profiled. Numeric measures of success reported included course grades, passing rates, and in one case, formal pre- and post-testing of core concepts. Reported qualitative measures consisted mostly of course evaluation results and less formal judgments about a course's success by the mathematics program chair. (Note that this is not the same as the enrollment-based definition of success used in selecting potential respondents for Phase 3 of the study.) Compilation of the above measures allowed a rating of the success of each course to be assigned, and courses showing strength in all reported measures received a "high" success rating. A weakness in one reported measure reduced the success rating to "moderate," while courses with more than one deficiency received a "weak" success rating. This rating of internal success does not appear to be related to CUPM consistency.

The degree of faculty effort required to support student learning in the course is a judgment based on personal conversations with the mathematics program chair at each

institution. This is distinguished from the departmental support variable (discussed later) in terms of personal effort, and interest in the course content, required of individual faculty members in teaching the course. Each course was rated as requiring either a "high" or "moderate" level of individual faculty effort. The parameters of the CUPM recommendations, particularly those related to real-world applications, communication, and fostering student confidence and engagement, make it unlikely that a course requiring a "low" amount of individual faculty effort would be selected for inclusion in Phase 3 of this study. In all but two of the courses examined, the faculty effort rating was equal to the overall CUPM consistency rating, indicating that the investment of individual faculty in teaching the course may be a significant factor in the degree to which the course meets the CUPM recommendations.

Actual course enrollments during the fall semester of the 2010-11 academic year were considered in determining which courses and programs would be selected for examination in Phase 3 of the study. (Recall that the basis for this threshold was an assumption that a course taken by all undergraduates during an eight-semester program would enroll approximately 12.5% of undergraduates in any given semester.) Consequently, each of the six individual courses considered enrolled at least ten percent of the institution's full-time undergraduate population in that semester. The two remaining courses, enrolling six and four percent of the college's population, comprise a comprehensive program that meets the enrollment criteria in combination. While most courses and programs considered in Phase 3 enrolled between ten and fifteen percent of their institution's full-time undergraduate population, one had enrollment of eighteen

percent of the institution's undergraduate population in a single semester. This is particularly impressive given that the course is not specifically required within the institution's core curriculum.

The colleges and universities examined in Phase 3 vary somewhat in their approaches to core curriculum requirements. While four of the seven institutions allow undergraduates to choose from a list of courses satisfying the general education requirement, two require all students to take the specific QL courses profiled in the preceding chapter. One institution blends these approaches, requiring all students to take a specific course, but exempting those students whose programs require calculus or discrete mathematics.

Of the operational variables described above, only the choice of textbook and individual faculty effort required seem to be related to the consistency of a course with the CUPM recommendations. Unfortunately, a high degree of compliance with the CUPM ideals appears difficult to achieve with commercial textbooks, leaving mathematics departments to create their own course materials. In many cases, this task will increase the individual faculty effort required.

Philosophical Variables

As contrasted to individual faculty effort, the philosophical variable of departmental support concerns the extent to which the mathematics department as a whole is committed to the course. In a tangible sense, this support may take the form of regular meetings between instructors of multiple sections of the course, common syllabi and/or assessments, and other formal efforts to support teaching in the course. More

abstract are the general attitudes of mathematics faculty toward the course, as expressed by the mathematics program chair. This level of departmental support was rated for each course examined, with most courses rated as having "strong" departmental support. The two "moderate" listings were the result of indications of generalized disenchantment with the course among the mathematics faculty. In contrast to the level of individual faculty effort, there appears to be little relationship between departmental support and CUPM consistency, perhaps because most of the courses examined have strong departmental support.

Institutional support appears to be a factor in the degree to which courses meet the CUPM recommendations. In an ideal world, the administration of colleges and universities would support QL courses by providing sufficient faculty resources to staff an adequate number of sections, supporting faculty release time to develop course materials, and enacting core curricular requirements that encourage students to enroll in the courses. Several comments on Phase 2 surveys cited inadequate staffing as a reason for not offering QL programs. However, in classifying institutional support as "strong" or "moderate" for the courses profiled, this rating included not only the concrete resources listed above, but also the attitude of faculty beyond the mathematics department as reported by the program chair. A "strong" rating on this variable resulted from the absence of negative comments related to administrative support, mixed with positive comments about the attitudes of faculty beyond the mathematics department. Ratings of "moderate" indicate concern expressed over staffing resources or neutral comments regarding non-mathematics faculty members' view of the course. While six of

the eight courses were rated as having "strong" institutional support, the two rated as "moderate" on this variable seem to achieve only moderate CUPM consistency. Therefore, it is possible that strong institutional support may be a necessary condition for developing a QL program that conforms to the CUPM ideals.

The final philosophical variable to be considered is the motivation for creation of the course. Rather than rating this variable on the same scale as others, an effort was made to identify the fundamental rationale for creation (or redesign) of the course into its current form. Three primary forms of motivation appeared in the Phase 3 interviews. The first, termed "remedy," was to correct deficiencies in a previously-existing course, or to avoid forcing students to repeat the same type of mathematics learned in secondary school. In other words, the institution and/or mathematics department recognized that a problem existed, and acted to fix it. The second major form of motivation was to encourage student success and understanding of quantitative matters in the real world, listed as "success." Finally, two of the courses were motivated by substantial changes in the institution's general education philosophy ("GE Philos"). As can be seen in Table 9, courses may arise from any combination of these motivations, and the degree of CUPM consistency appears unrelated to the rationale for the course.

Within the philosophical variables of departmental and institutional support, and the motivation for a course, the data seem to show only that institutional support may be a necessary factor in the quality of the course as measured by CUPM standards. However, since most courses received "strong" ratings in departmental support, the impact of this variable may be obscured. It seems logical to conclude that courses

lacking strong departmental support may be less likely to satisfy the recommendations of the CUPM.

To summarize, of the ten variables analyzed as factors possibly contributing to a course's consistency with the CUPM recommendations, only three or four seem clearly associated with this measure of the course's success. Operationally, courses with high CUPM consistency seem to require a high degree of individual faculty effort and intellectual investment, along with a commitment to the creation of course-specific textual materials to support student learning. Philosophically, strong institutional support for the course seems to be a necessary, but not sufficient, factor in developing a successful course, and departmental support may follow the same pattern. In the next chapter, we will further develop the ideas of course creation gained through these findings, and will begin to answer the research questions that guided this study.

Institution & Course Identification	Course Maturity	Textbook	Assessment	Internal Success	Faculty Effort	Enrollment	Required in Core?[1]	Departmental Support	Institutional Support	Motivation	CUPM Consistency
Artis: Mathematics & Philosophy	Mature	Reform	Strong	High	Moderate	13%	Yes – 1st semester	Strong	Strong	Remedy	High
Magistra: College Mathematics	Mature	Reform	Moderate	High	Moderate	14%	No – list	Strong	Moderate	Remedy + Success	Moderate
Scientia: Social Issues in College Algebra	Mature	Custom	Moderate	Moderate	High	12%	No – list	Strong	Strong	Remedy	High
Sumus: Problem Solving (Note: Two courses, enrollments considered together)	New	Custom	Strong	Moderate	High	6%	No – list	Strong	Strong	Success	High
Sumus: Modeling (Note: Two courses, enrollments considered together)	New	Reform	Moderate	Moderate	High	4%	No – list	Strong	Strong	Remedy	Moderate
Natura: Quantitative Reasoning Core	New	Reform	Moderate	Weak	Moderate	10%	No – exempt	Moderate, decreasing	Strong	Remedy + Success + GE Philos	Moderate
Petimus: Modeling Quantitative Information	New	Custom	Moderate	Moderate	High	18%	No – list	Moderate	Strong	Remedy	High
Verum: Great Ideas Core	New	Traditional	Weak	High	Moderate	14%	Yes – anytime	Strong	Moderate	Success + GE Philos	Moderate

Table 9. Summary of case study variables

[1] "List" means the student is able to choose from a list of courses satisfying the core requirement. "Exempt" means that while most undergraduate are required to take the specific course, some students are exempted by virtue of a course required by their major program.

Chapter 8. Conclusions and Recommendations

This study began as an effort to answer several questions related to the teaching of QL at small colleges and universities in the United States, as it exists nearly twenty years following the genesis of contemporary philosophies surrounding the place of QL in the undergraduate core curriculum. The first three research questions addressed the nature and definition of QL in its ideal form as recommended by the CUPM (2004), and as it is actually practiced in small institutions around the country.

CUPM Recommendations

This study has repeatedly referenced the recommendations of the CUPM as the standard by which effective QL programs should be evaluated. The 2004 Curriculum Guide (CUPM, 2004) encourages the design of programs that foster student confidence and engagement in mathematics, enhance students' skills in quantitative reasoning, communication, and problem solving, and promote critical thinking about mathematical issues arising in work and life.

In general, authors in the field (Catalano, 2010; Fisher & Saunders, 2006; Madison, 2003a, 2004; Small, 2006) have cited the failure of traditional mathematics programs, designed to prepare students for calculus, to meet the standards outlined by CUPM. Therefore, this study has concentrated primarily on identifying courses whose descriptions in institutional catalogs reflect a focus on quantitative reasoning and real-world applications of mathematics. Such courses, recognized through document-based research in Phase 1 of the study, were further investigated in Phases 2 and 3 to ascertain the degree to which they actually conformed to the CUPM recommendations.

Core Curricula and Course Offerings

While QL offerings may have improved in the past two decades, data gathered in Phase 1 of the study show that we still have a long way to go in the actual practice of QL education to ensure that all students have access to mathematics that is meaningful for them (Ganter, 2006). We need to continue efforts to increase offerings in QL (and statistics) at all institutions, and discourage a "one size fits all" approach focused on preparing students for calculus (Madison, 2006). (In five percent of the institutions examined in Phase 1 of this study, the *only* courses acceptable for core curriculum credit are those in the traditional sequence leading to calculus.)

Survey data gathered in Phase 2 of the study revealed that attitudes and practices surrounding QL in undergraduate general education are mixed, even among mathematics faculty at small institutions. Some respondents were frankly outspoken against QL, often citing the importance of the algorithmic approach contained in a traditional curriculum over teaching students to reason quantitatively. Others were in favor of QL efforts in principle, but noted that a scarcity of resources, particularly faculty staffing, prevented them from offering QL courses.

The good news arising out of the data collected in Phases 1 and 2 is that nearly three-quarters of institutions in the study population are, in fact, offering QL courses. While this is below the proportion of colleges and universities offering traditional or statistics courses, the acceptability of QL courses for core curricular requirements is approximately the same as that of traditional or statistics courses. However, QL courses

at most of these institutions are isolated, enrolling fewer than five percent of an institution's undergraduates in a given semester.

Successful QL Programs

Phase 3 of the study profiled courses and programs that could be considered successful models of QL education, both in terms of meeting the CUPM guidelines and in terms of actual course enrollments. The study found that institutional (and probably departmental) support is a necessary factor in the development and offering of courses consistent with CUPM recommendations. Other factors apparently important in the success of QL courses are the effort expended by individual mathematics faculty in teaching the course, and the development of course-specific texts used to support instruction. Based on the case study data, it appears that QL courses using commercial texts are less likely to show a high degree of conformity with CUPM guidelines.

Balancing General Education and the Mathematics Major

Investigation of the fourth research question, that of serving both the mathematics major and the general education population using shared resources, occurred in the context of Phase 3 of the study. Most of the mathematics program chairs interviewed identified several common strategies for balancing these needs. The first strategy pursued at institutions with a small number of majors (fewer than five graduates per year) in the mathematical sciences is to offer upper-level courses on an alternate-year rotation. Although this approach requires careful sequencing of courses and relatively flexible prerequisites, it is used successfully at most of the respondent institutions.

The second-most common strategy used at Phase 3 institutions is to relieve the staffing burden of lower-level (i.e., general education) courses by using adjunct or part-time faculty, thus allowing full-time faculty to use their prescribed teaching load for upper-level courses. While many adjunct or part-time faculty are wonderful instructors, this strategy could threaten the quality of instruction in the general education program. In fact, several of the Phase 3 respondents noted a conscious decision to avoid using adjunct instructors for their QL courses because of the difficulty of maintaining a consistent philosophical approach to the course.

The third strategy used in servicing the major is for mathematics faculty to routinely teach "overloads," meaning to exceed their contractual obligations to teach a certain number of course sections or credit hours per year. This strategy is in use at several of the colleges and universities profiled in Chapter 6.

Since many of the institutions use similar approaches to balancing the needs of the major with the needs of the general population of undergraduates, only at the two institutions using slightly different tactics were these strategies included in the case study reports. Sumus College is fortunate to have a large number of mathematics majors, sufficient to offer most upper-level courses at least once each year, although mathematics faculty routinely teach some of these courses as "overloads." Verum University, while serving a small number of majors, has made a pedagogically-based decision to offer two of their courses in the major at least annually. The department has gained institutional support to offer these courses, a transition course developing concepts of mathematical

proof and logic, and a capstone course for majors, even if annual enrollments are extremely low.

Recommendations for Practice

This study yielded several areas for improvement of practices related to QL at small colleges and universities. These can be divided into several categories.

Assessment of QL. Throughout this study, the assessment of the degree to which a course or program is consistent with the CUPM recommendations relied upon the judgment of the researcher. Although a formal assessment of outcomes and habits of mind associated with effective learning in QL has been designed by the American Association of Colleges and Universities (AAC&U, 2010), few of the institutions profiled in the case studies for this research are using the AAC&U rubric to assess the success of their QL programs. More widespread usage of this rubric, or a similar objective measure of student achievement in QL, would enable researchers to more reliably evaluate and compare programs and courses.

Print-based resources for teaching QL. The finding that effective teaching of QL may rely on the preparation of materials specific to a particular course and/or institution was troubling, given the array of commercially-published textbooks available. As noted in Chapter 2, demands on faculty at small colleges and universities are extensive, and the need for labor-intensive creation of course materials seems to add to that load. It is therefore recommended that publishers and authors share the burden of creating and providing appropriate materials *designed to support learning in the spirit of the CUPM recommendations*. If a variety of such materials were readily available, mathematics

departments might be encouraged to use the materials as a basis for creating course offerings with a greater degree of conformity to the CUPM guidelines.

Preparation of faculty. The high level of faculty effort found to be important in teaching effective QL courses suggests that specialized preparation of mathematics faculty to teach such courses may be necessary. While the specific practices, attitudes, and habits of mind needed among faculty members teaching QL courses should be determined through future research, both doctoral-granting institutions and small colleges and universities themselves should focus on providing prospective teachers of QL courses with appropriate training in how to teach the general population of undergraduates the reasoning, communication, and problem-solving skills needed in order to engage in quantitative situations faced throughout life.

Recognition of the importance of QL. As was seen in the studies by the American Council of Trustees and Alumni (ACTA, 2004, 2010), the general public remains unconvinced about the need for and validity of QL education in liberal arts core curricula. Unfortunately, as revealed by the survey and interview data in Phases 2 and 3 of this study, this viewpoint is often reflected among institutional administrators, and even mathematics faculty at some institutions. Broad educational efforts are needed to encourage these three groups to support the goals and objectives of QL education among the general population of undergraduates. This support should appear not only in a philosophical sense, but in the concrete area of institutional resources, such as staffing and course scheduling, dedicated to supporting QL.

Recommendations for Research

This study has revealed more questions than answers. Some areas of necessary research arise from the recommendations for practice discussed above, particularly the development of instruments to objectively assess QL courses and programs, and the development of print resources to support teaching and learning consistent with CUPM recommendations.

An additional area of recommended research arises from the finding that individual faculty instructional effort is important in successful courses and programs. This study considered such effort in a very broad sense, and future studies should narrow the view of faculty effort to identify particular instructional activities that contribute to a course or program's CUPM consistency.

Finally, although the focus of this study was on small college and universities, similar studies should be conducted that examine the nature and extent of QL education at medium and large colleges and universities to explore whether similar patterns of course offerings and general education acceptability occur at those institutions.

The first two decades of applying contemporary theories in developing quantitative reasoning across the undergraduate population have seen some promising growth and development in this field. However, mathematicians and mathematics educators need to assume responsibility for further development and public education about the value of creating a quantitatively literate society.

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Appendix A

Institutional Data Sheet

Institution Data Sheet

DOE ID 999999   Institution Sample College   City/State

Calendar   2009 FTE Enrollment   2009 UG Enrollment   2009 % Female   2009 % Black non-Hispanic   2009 % Hispanic   2009 % White non-Hispanic

Endowment per FTE 08/09   Revenue per FTE 08/09   Expenses per FTE 08/09   Selectivity

Accrediting Agency   % UG Living On-Campus   % of first-yrs in top decile of HS class

Catalog Information

Catalog URL   Access Date

Registrar Name   Registrar E-mail

Quantitative Core Requirement

Math Department Information

Math Dept URL   Math-related majors

Math Chair Name   Phone

Math Chair E-mail   E-mail 1   E-mail 2   Resp Date

Math Courses Below Calculus and Courses Satisfying Quantitative Core

Questions

Initial Notes

Initial Classification

Final Classification

Followup notes

Appendix B

List of Subject Colleges and Universities

Adrian College, Adrian, MI
Agnes Scott College, Decatur, GA
Albertus Magnus College, New
    Haven, CT
Albion College, Albion, MI
Alderson-Broaddus College,
    Philippi, WV
Alfred University, Alfred, NY
Allen University, Columbia, SC
Alma College, Alma, MI
Alvernia University, Reading, PA
Amherst College, Amherst, MA
Anderson University, Anderson, IN
Andrews University, Berrien
    Springs, MI
Aquinas College, Grand Rapids, MI
Asbury College, Wilmore, KY
Augustana College, Sioux Falls, SD
Austin College, Sherman, TX
Ave Maria University, Ave Maria, FL
Averett University, Danville, VA
Baker University, Baldwin City, KS
Bard College, Annandale-on-
    Hudson, NY
Bard College at Simon's Rock/Simons
    Rock College of Bard, Great
    Barrington, MA
Barton College, Wilson, NC
Bates College, Lewiston, ME
Belmont Abbey College, Belmont, NC
Beloit College, Beloit, WI
Benedictine College, Atchison, KS
Bennett College for Women,
    Greensboro, NC
Bennington College, Bennington, VT
Berea College, Berea, KY
Berry College, Mount Berry, GA
Bethany College, Bethany, WV
Bethany College, Lindsborg, KS

Bethel College, North Newton, KS
Bethel College, Mishawaka, IN
Birmingham-Southern College,
    Birmingham, AL
Blackburn College, Carlinville, IL
Bloomfield College, Bloomfield, NJ
Blue Mountain College, Blue
    Mountain, MS
Bluefield College, Bluefield, VA
Bluffton University, Bluffton, OH
Bowdoin College, Brunswick, ME
Brescia University, Owensboro, KY
Brevard College, Brevard, NC
Briar Cliff University, Sioux City, IA
Bridgewater College, Bridgewater, VA
Bryan College, Dayton, TN
Bryn Mawr College, Bryn Mawr, PA
Cabrini College, Radnor, PA
Caldwell College, Caldwell, NJ
Carleton College, Northfield, MN
Carlow University, Pittsburgh, PA
Carroll College, Helena, MT
Carson-Newman College, Jefferson
    City, TN
Castleton State College, Castleton, VT
Catawba College, Salisbury, NC
Cedar Crest College, Allentown, PA
Centenary College, Hackettstown, NJ
Centenary College of Louisiana,
    Shreveport, LA
Central College, Pella, IA
Central Methodist University,
    Fayette, MO
Centre College, Danville, KY
Chatham University, Pittsburgh, PA
Chestnut Hill College, Philadelphia, PA
Christian Brothers University,
    Memphis, TN
Claflin University, Orangeburg, SC

Claremont McKenna College, Claremont, CA
Clarke College, Dubuque, IA
Clearwater Christian College, Clearwater, FL
Coe College, Cedar Rapids, IA
Coker College, Hartsville, SC
Colby College, Waterville, ME
College of Idaho, Caldwell, ID
College of Mount St. Joseph, Cincinnati, OH
College of Mount St. Vincent, Riverdale, NY
College of Notre Dame of Maryland, Baltimore, MD
College of St. Mary, Omaha, NE
College of St. Elizabeth, Morristown, NJ
College of the Ozarks, Point Lookout, MO
College of Wooster, Wooster, OH
Colorado College, Colorado Springs, CO
Columbia College, Columbia, SC
Concordia University, Irvine, CA
Concordia University, Seward, NE
Concordia University, Ann Arbor, MI
Concordia University Chicago, River Forest, IL
Concordia University Texas, Austin, TX
Concordia University: St. Paul, St. Paul, MN
Connecticut College, New London, CT
Converse College, Spartanburg, SC
Corban College, Salem, OR
Cornell College, Mount Vernon, IA
Cornerstone University, Grand Rapids, MI
Covenant College, Lookout Mountain, GA
Culver-Stockton College, Canton, MO
Cumberland University, Lebanon, TN
Daemen College, Amherst, NY
Dakota State University, Madison, SD

Dakota Wesleyan University, Mitchell, SD
Davidson College, Davidson, NC
Davis and Elkins College, Elkins, WV
Defiance College, Defiance, OH
Doane College, Crete, NE
Dominican College of Blauvelt, Orangeburg, NY
Dominican University, River Forest, IL
Dordt College, Sioux Center, IA
Drew University, Madison, NJ
D'Youville College, Buffalo, NY
Earlham College, Richmond, IN
East Texas Baptist University, Marshall, TX
Eastern Mennonite University, Harrisonburg, VA
Eastern Nazarene College, Quincy, MA
Edgewood College, Madison, WI
Elmira College, Elmira, NY
Elms College, Chicopee, MA
Emmanuel College, Boston, MA
Emory & Henry College, Emory, VA
Erskine College, Due West, SC
Eureka College, Eureka, IL
Evangel University, Springfield, MO
Felician College, Lodi, NJ
Ferrum College, Ferrum, VA
Fisk University, Nashville, TN
Florida Memorial University, Miami Gardens, FL
Florida Southern College, Lakeland, FL
Fontbonne University, St. Louis, MO
Franciscan University of Steubenville, Steubenville, OH
Franklin College, Franklin, IN
Franklin Pierce University, Rindge, NH
Freed-Hardeman University, Henderson, TN
Fresno Pacific University, Fresno, CA
Gallaudet University, Washington, DC
Geneva College, Beaver Falls, PA
George Fox University, Newberg, OR

Georgetown College, Georgetown, KY

Georgia Southwestern State University, Americus, GA

Georgian Court University, Lakewood, NJ

Gordon College, Wenham, MA

Goshen College, Goshen, IN

Goucher College, Baltimore, MD

Grace College, Winona Lake, IN

Graceland University, Lamoni, IA

Grand View University, Des Moines, IA

Greensboro College, Greensboro, NC

Greenville College, Greenville, IL

Grinnell College, Grinnell, IA

Gwynedd-Mercy College, Gwynedd Valley, PA

Hamilton College, Clinton, NY

Hamline University, St. Paul, MN

Hampden-Sydney College, Hampden-Sydney, VA

Hampshire College, Amherst, MA

Hannibal-LaGrange College, Hannibal, MO

Hanover College, Hanover, IN

Hardin-Simmons University, Abilene, TX

Hartwick College, Oneonta, NY

Hastings College, Hastings, NE

Haverford College, Haverford, PA

Heidelberg University, Tiffin, OH

Hendrix College, Conway, AR

Heritage University, Toppenish, WA

Hillsdale College, Hillsdale, MI

Hiram College, Hiram, OH

Hollins University, Roanoke, VA

Holy Family University, Philadelphia, PA

Hood College, Frederick, MD

Howard Payne University, Brownwood, TX

Huntingdon College, Montgomery, AL

Huntington University, Huntington, IN

Huston-Tillotson University, Austin, TX

Illinois College, Jacksonville, IL

Iowa Wesleyan College, Mount Pleasant, IA

Jamestown College, Jamestown, ND

John Brown University, Siloam Springs, AR

Johnson C. Smith University, Charlotte, NC

Johnson State College, Johnson, VT

Judson College, Marion, AL

Judson University, Elgin, IL

Juniata College, Huntingdon, PA

Kalamazoo College, Kalamazoo, MI

Kansas Wesleyan University, Salina, KS

Kentucky Wesleyan College, Owensboro, KY

Kenyon College, Gambier, OH

Keuka College, Keuka Park, NY

King College, Bristol, TN

Knox College, Galesburg, IL

La Roche College, Pittsburgh, PA

La Sierra University, Riverside, CA

LaGrange College, LaGrange, GA

Lake Erie College, Painesville, OH

Lake Forest College, Lake Forest, IL

Lambuth University, Jackson, TN

Lasell College, Newton, MA

Lawrence University, Appleton, WI

Lebanon Valley College, Annville, PA

LeMoyne-Owen College, Memphis, TN

Lenoir-Rhyne University, Hickory, NC

Lesley University, Cambridge, MA

Lewis & Clark College, Portland, OR

Lincoln Memorial University, Harrogate, TN

Lindsey Wilson College, Columbia, KY

Linfield College, McMinnville, OR

Livingstone College, Salisbury, NC

Louisiana College, Pineville, LA

Lubbock Christian University, Lubbock, TX

Lycoming College, Williamsport, PA

Lyndon State College, Lyndonville, VT

Lyon College, Batesville, AR
Macalester College, St. Paul, MN
Maharishi University of Management, Fairfield, IA
Malone University, Canton, OH
Manchester College, North Manchester, IN
Manhattanville College, Purchase, NY
Marian University, Indianapolis, IN
Marian University, Fond du Lac, WI
Marietta College, Marietta, OH
Marlboro College, Marlboro, VT
Mars Hill College, Mars Hill, NC
Mary Baldwin College, Staunton, VA
Marygrove College, Detroit, MI
Maryville College, Maryville, TN
Massachusetts College of Liberal Arts, North Adams, MA
Master's College and Seminary, Santa Clarita, CA
Mayville State University, Mayville, ND
McDaniel College, Westminster, MD
McKendree University, Lebanon, IL
McMurry University, Abilene, TX
McPherson College, McPherson, KS
Medaille College, Buffalo, NY
Meredith College, Raleigh, NC
Merrimack College, North Andover, MA
Methodist University, Fayetteville, NC
MidAmerica Nazarene University, Olathe, KS
Mid-Continent University, Mayfield, KY
Midland Lutheran College, Fremont, NE
Midway College, Midway, KY
Miles College, Fairfield, AL
Milligan College, Milligan College, TN
Mills College, Oakland, CA
Millsaps College, Jackson, MS
Missouri Valley College, Marshall, MO
Monmouth College, Monmouth, IL
Moravian College, Bethlehem, PA
Morningside College, Sioux City, IA

Morris College, Sumter, SC
Mount Marty College, Yankton, SD
Mount Mary College, Milwaukee, WI
Mount Mercy College, Cedar Rapids, IA
Mount St. Mary's College, Los Angeles, CA
Mount St. Mary's University, Emmitsburg, MD
Mount Vernon Nazarene University, Mount Vernon, OH
Muskingum University, New Concord, OH
Nebraska Wesleyan University, Lincoln, NE
New England College, Henniker, NH
New Mexico Highlands University, Las Vegas, NM
New Mexico Institute of Mining and Technology, Socorro, NM
Newberry College, Newberry, SC
Newman University, Wichita, KS
Nichols College, Dudley, MA
North Carolina Wesleyan College, Rocky Mount, NC
North Park University, Chicago, IL
Northland College, Ashland, WI
Northwest Christian University, Eugene, OR
Northwest Nazarene University, Nampa, ID
Northwest University, Kirkland, WA
Northwestern College, Orange City, IA
Northwestern Oklahoma State University, Alva, OK
Notre Dame College, Cleveland, OH
Nyack College, Nyack, NY
Oakland City University, Oakland City, IN
Oakwood University, Huntsville, AL
Occidental College, Los Angeles, CA
Oglethorpe University, Atlanta, GA
Ohio Wesleyan University, Delaware, OH

Oklahoma Baptist University, Shawnee, OK

Oklahoma Christian University, Edmond, OK

Oklahoma Panhandle State University, Goodwell, OK

Oklahoma Wesleyan University, Bartlesville, OK

Olivet College, Olivet, MI

Ottawa University, Ottawa, KS

Ouachita Baptist University, Arkadelphia, AR

Our Lady of the Lake University of San Antonio, San Antonio, TX

Pacific Union College, Angwin, CA

Pacific University, Forest Grove, OR

Paine College, Augusta, GA

Peru State College, Peru, NE

Pfeiffer University, Misenheimer, NC

Philander Smith College, Little Rock, AR

Piedmont College, Demorest, GA

Pikeville College, Pikeville, KY

Pitzer College, Claremont, CA

Polytechnic Institute of New York University, Brooklyn, NY

Pomona College, Claremont, CA

Presbyterian College, Clinton, SC

Principia College, Elsah, IL

Queens University of Charlotte, Charlotte, NC

Quincy University, Quincy, IL

Randolph College, Lynchburg, VA

Randolph-Macon College, Ashland, VA

Reed College, Portland, OR

Regent University, Virginia Beach, VA

Rhodes College, Memphis, TN

Ripon College, Ripon, WI

Rivier College, Nashua, NH

Roanoke College, Salem, VA

Roberts Wesleyan College, Rochester, NY

Rockford College, Rockford, IL

Rocky Mountain College, Billings, MT

Russell Sage College, Troy, NY

Rust College, Holly Springs, MS

Saint Anselm College, Manchester, NH

Saint Bonaventure University, St. Bonaventure, NY

Saint Joseph College, West Hartford, CT

Saint Joseph's College, Rensselaer, IN

Saint Joseph's College of Maine, Standish, ME

Saint Leo University, Saint Leo, FL

Saint Martin's University, Lacey, WA

Saint Mary's College, Notre Dame, IN

Saint Michael's College, Colchester, VT

Salem College, Winston-Salem, NC

Salve Regina University, Newport, RI

San Diego Christian College, El Cajon, CA

Schreiner University, Kerrville, TX

Scripps College, Claremont, CA

Seton Hill University, Greensburg, PA

Sewanee: The University of the South, Sewanee, TN

Shenandoah University, Winchester, VA

Shorter University, Rome, GA

Siena Heights University, Adrian, MI

Silver Lake College, Manitowoc, WI

Simmons College, Boston, MA

Simpson College, Indianola, IA

Simpson University, Redding, CA

South Dakota School of Mines and Technology, Rapid City, SD

Southern Nazarene University, Bethany, OK

Southern Wesleyan University, Central, SC

Southwestern Adventist University, Keene, TX

Southwestern College, Winfield, KS

Southwestern University, Georgetown, TX

Spring Hill College, Mobile, AL

St. Augustine's College, Raleigh, NC

St. Francis University, Loretto, PA
St. Gregory's University, Shawnee, OK
St. Joseph's College, Brooklyn, NY
St. Mary-of-the-Woods College, St.
    Mary-of-the-Woods, IN
St. Mary's College of Maryland, St.
    Mary's City, MD
St. Paul's College, Lawrenceville, VA
St. Vincent College, Latrobe, PA
Sterling College, Sterling, KS
Stillman College, Tuscaloosa, AL
Swarthmore College, Swarthmore, PA
Sweet Briar College, Sweet Briar, VA
Tabor College, Hillsboro, KS
Talladega College, Talladega, AL
Taylor University, Upland, IN
Tennessee Wesleyan College,
    Athens, TN
Texas Lutheran University, Seguin, TX
Texas Wesleyan University, Fort
    Worth, TX
Thiel College, Greenville, PA
Thomas More College, Crestview
    Hills, KY
Tougaloo College, Tougaloo, MS
Transylvania University, Lexington, KY
Trevecca Nazarene University,
    Nashville, TN
Trine University, Angola, IN
Trinity Christian College, Palos
    Heights, IL
Trinity International University,
    Deerfield, IL
Trinity Washington University,
    Washington, DC
Union College, Lincoln, NE
Union College, Barbourville, KY
University of Alaska Southeast,
    Juneau, AK
University of Dallas, Irving, TX
University of Great Falls, Great
    Falls, MT

University of Houston-Victoria,
    Victoria, TX
University of Mary, Bismarck, ND
University of Minnesota: Morris,
    Morris, MN
University of Mobile, Mobile, AL
University of Montana: Western,
    Dillon, MT
University of Pittsburgh at Bradford,
    Bradford, PA
University of Pittsburgh at Greensburg,
    Greensburg, PA
University of Rio Grande, Rio
    Grande, OH
University of Science and Arts of
    Oklahoma, Chickasha, OK
University of Sioux Falls, Sioux
    Falls, SD
University of St. Francis, Fort
    Wayne, IN
University of St. Francis, Joliet, IL
University of Saint Mary,
    Leavenworth, KS
University of St. Thomas, Houston, TX
University of the Cumberlands,
    Williamsburg, KY
University of the Ozarks,
    Clarksville, AR
University of Virginia's College at Wise,
    Wise, VA
University of West Alabama,
    Livingston, AL
Ursinus College, Collegeville, PA
Ursuline College, Pepper Pike, OH
Valley City State University, Valley
    City, ND
Vanguard University of Southern
    California, Costa Mesa, CA
Virginia Military Institute,
    Lexington, VA
Virginia Union University,
    Richmond, VA
Virginia Wesleyan College, Norfolk, VA

Viterbo University, LaCrosse, WI
Voorhees College, Denmark, SC
Wabash College, Crawfordsville, IN
Wagner College, Staten Island, NY
Walla Walla University, College
        Place, WA
Warren Wilson College, Swannanoa, NC
Wartburg College, Waverly, IA
Washington & Jefferson College,
        Washington, PA
Washington and Lee University,
        Lexington, VA
Washington College, Chestertown, MD
Wayland Baptist University,
        Plainview, TX
Waynesburg University,
        Waynesburg, PA
Wells College, Aurora, NY
Wesleyan College, Macon, GA
West Virginia Wesleyan College,
        Buckhannon, WV
Western New Mexico University, Silver
        City, NM

Westminster College, Fulton, MO
Westmont College, Santa Barbara, CA
Wheaton College, Norton, MA
Wheeling Jesuit University,
        Wheeling, WV
Whitman College, Walla Walla, WA
Whittier College, Whittier, CA
Wiley College, Marshall, TX
Willamette University, Salem, OR
William Carey University,
        Hattiesburg, MS
William Jewell College, Liberty, MO
William Penn University, Oskaloosa, IA
William Woods University, Fulton, MO
Wilmington College, Wilmington, OH
Wilson College, Chambersburg, PA
Wingate University, Wingate, NC
Wisconsin Lutheran College,
        Milwaukee, WI
Wittenberg University, Springfield, OH
Wofford College, Spartanburg, SC
York College, York, NE

Appendix C

E-Mail Soliciting Survey Participation by

Mathematics Program Chair in Phase 2 of Data Collection

DATE:
TO:
SUBJECT: Seeking info for dissertation research

Dear Dr. ___,

You are invited to participate in a study of quantitative requirements at small colleges and universities. I hope to summarize institutional practices in quantitative literacy, and to compile a directory of best practices in quantitative literacy for use by small colleges in developing or revising their own programs. You were selected as a possible participant in this study because you are a mathematics department chair at one of the institutions identified for my study.

If you decide to participate, please complete the online survey related to your institution, accessible at [LINK]. The survey is designed to clarify information gained in my review of ___'s online catalog, and to solicit other information about course enrollments and resource allocation at your institution. It will take about 10-15 minutes. No benefits accrue to you for answering the survey, but your responses will be used to inform curriculum and course design at small colleges and universities. There are no risks or discomfort to you in completing the survey, other than those you encounter in everyday life.

Although the survey is necessarily unique to each institution in the study, all responses will be held confidential, and you and your institution will not be identified by name in my reporting. Your decision whether or not to participate will not affect your future relationships with me or Montclair State University. If you decide to participate, you are free to stop at any time. You may also skip questions if you don't want to answer them or may refuse to return the survey.

Please feel free to ask questions regarding this study. You may contact me later if you have additional questions at this e-mail address, or at (540) 221-4351. Should you wish to contact my faculty sponsor for information, Dr. Kenneth C. Wolff may be reached at (973) 655-7275, or at wolffk@mail.montclair.edu. Any questions about your rights may be directed to Dr. Debra Zellner, Chair of the Institutional Review Board at Montclair State University at reviewboard@mail.montclair.edu or 973-655-4327.

Thank you for your time.

Sincerely,
Jodie A. Miller
Ed.D. candidate
Montclair State University

Appendix D

Online Survey Completed by Mathematics

Program Chair in Phase 2 of Data Collection

ℤ zoomerang

999999 - Sample College

Created: January 31 2012, 7:37 PM
Last Modified: January 31 2012, 7:41 PM
Design Theme: Basic Blue
Language: English
Button Options: Custom: Start Survey: "Start Survey!" Submit: "Submit"
Disable Browser "Back" Button: False

999999 - Sample College

Page 1 - Heading

You are invited to participate in a study of quantitative requirements at small colleges and universities. I hope to summarize institutional practices in quantitative literacy, and to compile a directory of best practices in quantitative literacy for use by small colleges in developing or revising their own programs.You were selected as a possible participant in this study because you are a mathematics department chair (or their designee) at one of the institutions identified for my study.

The attached survey is designed to clarify information gained in my review of Sample College's online catalog, and to solicit other information about course enrollments and resource allocation at your insitution. It will take about 10-15 minutes. No benefits accrue to you for answering the survey, but your responses will be used to inform curriculum and course design at small colleges and universities. There are no risks or discomfort to you in completing the survey, other than those you encounter in everyday life.

Although the survey is necessarily unique to each institution in the study, all responses will be held confidential, and you and your institution will not be identified by name in my reporting of the survey data. Your decision whether or not to participate will not affect your future relationships with me or Montclair State University. If you decide to participate, you are free to stop at any time, you may also skip questions if you don't want to answer them or may refuse to return the survey.

Please feel free to ask questions regarding this study. You may contact me later if you have additional questions at millerj13@mail.montclair.edu, or at (540) 221-4351. Any questions about your rights may be directed to Dr. Debra Zellner, Chair of the Institutional Review Board at Montclair State University at reviewboard@mail.montclair.edu or (973) 655-4327.

Thank you for your time.
Sincerely,
Jodie A. Miller
Ed.D. candidate
Montclair State University

Page 1 - Question 1 - Open Ended - One Line

If you agree to participate in this study, please type your name in the space below. Typing your name acts as your signature, and indicates that you understand the risks and benefits as outlined above.

Page 1 - Question 2 - Open Ended - One Line

If you agree to allow me to use the data collected in future studies, please type your name in the space below. Typing your name acts as your signature, and indicates that you understand the risks and benefits as outlined above.

Page 2 - Question 3 - Open Ended - Comments Box

Institution-Specific Question(s): Approximately 45-50% of surveys had no institution-specific questions; 30-35% had one of these questions; and the remaining 15-20% had two or more of these questions. Please see Appendix E for specific questions.

Page 2 - Heading

Part of my study will examine actual course-taking patterns and instructor assignments for courses below calculus. The following questions relate to your Fall, 2010, offerings of courses listed in Sample College's online catalog.

Page 2 - Question 4 - Open Ended - One or More Lines with Prompt

Course #1

- ✎ # Sections Taught by Tenured or Tenure-Track Faculty
- ✎ # Sections Taught by Non-Tenure-Track or Adjunct Faculty
- ✎ # Students Enrolled

Page 2 - Question 5 - Open Ended - One or More Lines with Prompt

Course #2

- ✎ # Sections Taught by Tenured or Tenure-Track Faculty
- ✎ # Sections Taught by Non-Tenure-Track or Adjunct Faculty
- ✎ # Students Enrolled

Page 2 - Question 6 - Open Ended - Comments Box

If any of the courses listed above were not offered in Fall, 2010, when are they scheduled to be offered next?

Page 2 - Question 7 - Open Ended - One Line

How many full-time faculty are in the mathematics department at your institution?

Page 2 - Question 8 - Open Ended - One Line

On average, how many students earn degrees in mathematics from your institution each year?

Page 2 - Question 9 - Open Ended - Comments Box

How are incoming students placed in their initial mathematics course?

Page 2 - Question 10 - Open Ended - Comments Box

What methods do you use to ensure quality control in multi-section courses?

Page 2 - Question 11 - Open Ended - Comments Box

Does your department have any plans for new quantitative courses to be offered in the general education curriculum?

Page 2 - Question 12 - Open Ended - Comments Box

Is the mathematics department satisfied with the way the mathematics program at your institution serves students in the general population (who are not planning to continue to calculus)? Why or why not?

Page 2 - Question 13 - Open Ended - Comments Box

Are there any comments you would like to share about general education curricula in mathematics, or about efforts to teach quantitative reasoning to the general population of undergraduates?

Page 2 - Question 14 - Yes or No

Would your department like to receive a summary of my results (to be published in late 2011 or early 2012)?

○ Yes
○ No

Page 2 - Question 15 - Yes or No

May I contact your mathematics department chair by phone, if necessary, for further information on the mathematics program at your institution?

○ Yes
○ No

Thank You Page

Thank you for participating in my research on quantitative literacy programs at small colleges.

Appendix E

Institution-Specific Questions for Survey of

Mathematics Program Chairs in Phase 2 of Data Collection

- Do student choices between [list of quantitative literacy courses] appear to follow any pattern with regard to intended major or other factors?

- What was the impetus for the development of [course number]?

- What is the difference between [course number] and [course number], which seem to have similar course descriptions?

- What is the general profile (major, student interests, etc.) of students typically enrolled in [course number]?

- Is [course number] normally taught by one particular faculty member, or is teaching of this course shared among several faculty members?

- Is [course number] taught by members of the mathematics faculty? If not, who teaches it?

- What was the rationale for excluding [course number] from the list of courses satisfying the quantitative core curriculum?

- Is [course number] designed primarily for prospective elementary school teachers?

- Is it possible for students to take [course number] without the associated pedagogy lab?

- Are courses satisfying the quantitative core curriculum offered in departments beyond mathematics? If so, what disciplines offer such courses?

- To what degree is [mathematical content area] included in [course number]?

- Approximately what percent of students satisfy the quantitative core requirement through ACT, SAT, or other test scores?

- How is the mathematical content divided between [course numbers in a sequence]?

- Does the institution offer courses below calculus for students interested in advanced mathematics, but whose preparation may be weak?

- What factors create the demand for the variety of quantitative general education courses offered at the institution?

- What is the mathematical content of [course number]?

- How is [mathematical modeling theme] incorporated into [course number]?

- Approximately what percent of students take mathematics beyond the requirement of the core curriculum?

- In general, what pedagogical approach is used in teaching [course number]?

- How are topics for [course number] chosen each semester?

- Are [course numbers] consistently offered as a fall-spring sequence?

- What are the typical credit values (or number of meetings per week) of courses offered at your institution?

- I was unable to locate quantitative requirements in your institution's core curriculum. Does your institution require undergraduates to take any quantitative courses?

- It appears that the core curriculum requirements at your institution are in transition. How will the changes affect your department's offerings designed for the general population of undergraduates?

- What is the rationale behind charging course fees for the mathematics courses offered at your institution?

Appendix F

Guiding Questions for In-Depth Interview with

Mathematics Program Chairs in Phase 3 of Data Collection

Program History:

- When and why was the program started?

- How has it evolved since its inception?

Challenges:

- What were some of the greatest challenges in implementing the program?

- Have there been any challenges in keeping the program moving forward?

Mathematics and the Disciplines:

- How have disciplines beyond mathematics reacted to the inclusion of QL in the math curriculum?

Program Success:

- Is the program successful at your institution?

- What do you see as the reasons for its success (or lack of success)?

- What changes in student outcomes have you seen that could be attributed to the program (attitudes, achievement, further course-taking, etc.)?

Servicing the Major:

- What conflicts does your department encounter in servicing both the general populations of undergraduates and courses required for the mathematics major?

- What are your approaches for solving them?

Appendix G

Informed Consent Form for Phase 3 Respondents

MONTCLAIR STATE UNIVERSITY

College of Science and Mathematics
Department of Mathematical Sciences
Voice: 973-655-4263
Fax: 973-655-7686

CONSENT FORM FOR ADULTS

Please read below with care. You can ask questions at any time, now or later. You can talk to other people before you fill in this form.

Study's Title: A Study of Quantitative Requirements at Small Colleges and Universities

Why is this study being done? This study is being done to develop a comprehensive view of quantitative core curriculum requirements at small colleges and universities, and to examine in greater detail programs that appear consistent with the recommendations of the Mathematical Association of America (MAA) concerning quantitative literacy in undergraduate education. The study will focus on small institutions because there may be particular resource limitations that constrain their ability to offer comprehensive quantitative literacy programs.

What will happen while you are in the study? You have been selected for an in-depth interview in the third phase of this study because the general education program at your institution appears consistent with the recommendations of the MAA. During this phase of the study, you will have a telephone interview with the researcher lasting approximately 30-45 minutes, in which the researcher will explore reasons for the apparent success of the quantitative general education program at your institution. Although the researcher will take notes during the interview, this telephone interview will not be recorded. The researcher may need to contact you for clarification after the telephone interview; if this follow-up is necessary, it will be conducted by e-mail.

Time: The telephone interview will take about 30-45 minutes, arranged at a time mutually agreeable to you and the researcher. If e-mail follow-up is necessary, it is expected to be in the form of brief questions requiring no more than 10 minutes to answer.

Risks: You may experience some anxiety at being asked to share your thoughts about the quantitative core curriculum requirements at your own institution. These risks are no greater than those in everyday life.

Benefits: There is no direct benefit to you accrued from participating in this study. However, the results of this study will be used to inform quantitative curriculum and course design at small colleges and universities.

Who will know that you are in this study? You will not be linked to any presentations. We will keep who you are confidential according to the law.

Do you have to be in the study? You do not have to be in this study. You are a volunteer! It is okay if you want to stop at any time and not be in the study. You do not have to answer any questions you do not want to answer. Nothing will happen to you.

Do you have any questions about this study? Phone or email Jodie A. Miller, 216 Evershire St, Waynesboro, VA 22980, (540) 221-4351, millerj13@mail.montclair.edu. You may also contact my faculty sponsor, Dr. Kenneth C. Wolff at (973) 655-7275, wolffk@mail.montclair.edu.

APPROVED
SEP 13 2011
MSU INSTITUTIONAL REVIEW BOARD

Updated 9/18/2011   1

MONTCLAIR STATE UNIVERSITY

College of Science and Mathematics
Department of Mathematical Sciences
Voice: 973-655-4263
Fax: 973-655-7686

Do you have any questions about your rights? Phone or email the IRB Chair, Debra Zellner (reviewboard@mail.montclair.edu or (973) 655-4327).

It is okay to use my data in other studies:
Please initial: _____ Yes   _____ No

I would like to get a summary of this study:
Please initial: _____ Yes   _____ No

APPROVED
SEP 13 2011
MSU INSTITUTIONAL REVIEW BOARD

The copy of this consent form is for you to keep.

If you choose to be in this study, please fill in your lines below.

_____   _____   _____
Print your name here   Sign your name here   Date

Jodie A. Miller   *Jodie A. Miller*   9/27/2011
Name of Principal Investigator Signature   Date

Kenneth C. Wolff   *Kenneth C Wolff*   10/07/2011
Name of Faculty Sponsor   Signature   Date

Appendix H

Course Classifications and Descriptors

Course Classification	Description
Algebra 1, Without Quadratics (Traditional Cluster)	Includes solving and graphing linear equations. May include inequalities, functions, exponents, rational expressions, systems, functions, polynomials. Does not include quadratic equations/functions, factoring, radical expressions.
Algebra 1, With Quadratics (Traditional Cluster)	Includes solving and graphing linear and quadratic equations. May include radical expressions, rational expressions/equations, complex fractions, complex numbers. Does not include radical equations, exponential/logarithmic functions, matrices, transformations, polynomial division, nonlinear systems, combinatorics, symmetry.
Intermediate Algebra (Traditional Cluster)	Includes solving/graphing many function classes – linear, quadratic, polynomial, rational, radical, transcendental (typically exponential/logarithmic). May include binomial theorem, nonlinear or 3-variable systems, matrices, sequences/series, mathematical induction, function operations, transformations, analytic geometry, basic trigonometry, or conics. Does not include both trigonometry and conics.

Pre-Calculus (Traditional Cluster)	Includes many intermediate algebra topics plus significant trigonometry and/or conics. When trigonometry included without conics, context and other topics determine classification as intermediate algebra or pre-calculus. May include modeling (but modeling is not central to course description), coordinate or analytic geometry, limits, polar and/or parametric functions, vectors, continuity.
Quantitative Reasoning (Quantitative Literacy Cluster)	Focuses on quantitative reasoning in real-life context. Description may refer to social issues, consumerism, authentic applications, citizenship, uses of mathematics, and decision-making. May include references to critical thinking, communication, the structure of mathematics, and philosophy of mathematics.
Quantitative Topics (Quantitative Literacy Cluster)	May include topics common to quantitative reasoning courses, but description contains no reference to reasoning. Often a simple listing of topics, and may indicate that topics vary depending on instructor.
Statistics (Statistics Cluster)	Contains topics considered standard in algebra-based statistics course, particularly including both probability and inference. May also include ANOVA and/or reference to non-parametric statistics.
Trigonometry (Traditional Cluster)	Trigonometry in depth, usually including unit circle, right triangle, identities/proofs, Laws of Sine and Cosine, and equations. May also include conics, complex numbers, polar graphing, vectors, and parametric equations.

Discrete Mathematics (Professional Cluster)	Mixed topics that may include sets, sequences, counting, probability, matrix algebra, relations, functions, algorithms, ordering, binary operations, Boolean algebra, graph theory, logic, proof, automata, recursion. Typically focuses on mathematics needed for computer science applications.
Other (Other Cluster)	Course not fitting an otherwise-defined category.
Math History (Other Cluster)	Includes history of mathematics. May include ethno-mathematics or mathematics in cultural context.
Basic Math / Pre-Algebra (Traditional Cluster)	Focuses on low-level applications or operations with numbers (whole, integer, rational, decimal, percent). May include other topics in geometry, probability, or statistics, or may refer to "basic algebra." Does not include graphing.
Basic Statistics (Statistics Cluster)	Includes basic concepts of statistics, but course description is missing either probability or inference (or both). May include "introduction to inference" without specifying statistical methods. Does not include ANOVA.
Mathematics for Teachers (Professional Cluster)	Mathematical content course designed for prospective teachers (usually elementary and/or middle school levels). Includes content description consistent with NCTM content strands. Course description may include language related to in-depth arithmetic algorithms, integrated methods and content, manipulatives, activities approach, teaching strategies. Does not include field experience other than possible classroom observation.

Methods for Teaching Mathematics (Professional Cluster)	Focuses on methods for teaching mathematics including pedagogy, research, technology, classroom application, and possible field experience.
Business Mathematics (Professional Cluster)	Mixture of mathematical topics for business including specific business applications – linear programming, Markov chains, probability/statistics, operations research, break-even analysis, etc. Often called "Finite Mathematics." May include brief introduction to calculus.
Occupational Mathematics (Professional Cluster)	Focuses on mathematical topics for specific occupations or majors, often health sciences.
Geometry (Other Cluster)	Formal or informal geometry. May be taken by majors or non-majors, but does not have pre-calculus or higher as prerequisite.
Logic (Other Cluster)	Includes topics typical of symbolic logic curriculum.
Mathematical Modeling (Quantitative Literacy Cluster)	Mathematical modeling is central to course description. May include use of computers and typical intermediate algebra/pre-calculus topics.

Advanced Statistics (Statistics Cluster)	Includes topics beyond standard algebra-based statistics course, typically multiple regression, analysis of covariance, analysis of time series, advanced experimental design, and other statistical models specific to particular situations.
Computer Science and Technology (Other Cluster)	Course in computer science and/or use of technology for mathematics (calculator, computer, software).