UNIVERSITY OF CALIFORNIA

Los Angeles

Quantitative Literacy Across the Community College Curriculum: A Qualitative Case Study of Mathematics Across the Community College Curriculum (MAC^3)

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Education

by

Matthew Thomas Henes

2018

ABSTRACT OF THE DISSERTATION

Quantitative Literacy Across the Community College Curriculum:

A Qualitative Case Study of Mathematics Across the Community College Curriculum (MAC^3)

by

Matthew Thomas Henes

Doctor of Education

University of California, Los Angeles, 2018

Professor Christina A. Christie, Chair

This was a historical case study of a national professional development program, Mathematics Across the Community College Curriculum (MAC^3). MAC^3 was created to support community college faculty in using an interdisciplinary approach to embedding quantitative literacy in community college classes. Quantitative literacy is characterized by a habit of mind and the ability to work with numerical data to solve real-life problems, and it has been shown to be lacking in American college graduates. It is distinct from traditional mathematics in that it considers math in authentic, everyday contexts. To learn how individuals had incorporated interdisciplinary quantitative literacy into their curricula and the obstacles they faced, I interviewed 17 people—the two directors of MAC^3 and 15 community college faculty. The case study also included document and website analysis.

The evidence showed various levels of quantitative literacy implementation but no instances of a sustained interdisciplinary approach to the content. Key factors that supported implementation were participant motivation, the MAC^3 network itself, and, in some cases, administrative support. Lack of administrative support also acted as a limiting factor, together with math-avoidant faculty and financial obstacles. MAC^3 saw success in terms of exposure and benefits to faculty participants and to students. The main obstacles for quantitative literacy work related to logistical issues and sustainability.

The findings point to the need for convergence—that is, for faculty to work together with administrators to effect campuswide change—as well as professional development in order to implement and sustain interdisciplinary initiatives. These implications extend beyond quantitative literacy and can apply generally to widespread change on community college campuses. Although the sample was self-selected and comprised voluntary participants of MAC^3—and, as such, generalizability is limited—the study has valuable implications for practice and future study, both of which are discussed.

The dissertation of Matthew Thomas Henes is approved.

Megan L. Franke

Cecilia Rios-Aguilar

James W. Stigler

Christina A. Christie, Committee Chair

University of California, Los Angeles

2018

DEDICATION PAGE

This work is dedicated to my parents, Tom and Connie Henes, who never stopped believing in me.

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGEMENTS

This work would not have been possible without the guidance and support of Linda Rose and my chair, Tina Christie. For you I will always be grateful. I also thank my committee members, Megan Franke, Cecilia Rios-Aguilar, and James Stigler. I am indebted to you for your insights and for helping me design a study that was doable. Thank you, Cindy Kratzer. You are a gem. Your instruction has been invaluable. Finally, thank you to of the study participants for sharing your time and experience with me.

VITA

1997–2000	Associate of Science Riverside Community College Riverside, CA
2000–2002	Bachelor of Science (Pure Mathematics) University of California, Riverside, CA
2002–2005	Master of Arts (Mathematics) California State University, San Bernardino, CA
2002–2004	Teaching Assistant Department of Mathematics California State University, San Bernardino, CA
2004–2007	Adjunct Instructor Department of Mathematics Riverside Community College Riverside, CA
2004–2006	Adjunct Instructor Gateway to College Early College High School Riverside, CA
2005–2006	Adjunct Instructor Department of Mathematics Crafton Hills College Yucaipa, CA
2006–2007	Lecturer Department of Mathematics California State University, San Bernardino, CA
2006–2008	Mathematics Instructor Crafton Hills College Yucaipa, CA
2008–present	Associate Professor of Mathematics Pasadena City College Pasadena, CA
2015–present	Coordinator Division of Mathematics and Computer Science Pasadena City College Pasadena, CA

Chapter One:

Introduction and Problem Statement

Prior to each election, California voters receive a Voter Information Guide containing an analysis of each proposition on the upcoming ballot, arguments for and against each proposition, and the text of each bill. Statewide measures tend to involve large sums of money, which are referenced in the analysis of each measure. The analysis also often includes percentages that are related to the measure. A look at the 2016 California Voter Guide indicates that a large amount of *numeracy* is required to understand the analysis and arguments in order to make an informed ballot choice. In particular, voters need to have some understanding of the magnitude of large numbers to grasp how seemingly huge amounts are relatively small compared to an entire state's budget—for instance how $300 million can be less than one percent of the annual budget and what that means—or that $2,000 million is the same as $2 billion. Day to day, consumers need to know how interest affects both debt and investments in order to make sound financial decisions or the true costs of purchasing a home in order to consider whether buying or renting is a better choice. Further examples of the need for numeracy can be found in the media, in the jury box, at the doctor's office, and in the rhetoric of those running for public office.

Numeracy, a term popularized by John Paulos' bestselling 1988 book *Innumeracy: Mathematical Illiteracy and its Consequences* in 1988 (Root, 2009), is more commonly known in the United States as quantitative literacy (QL).[1] Quantitative literacy is one of three kinds of literacy recognized by the U.S. Department of Education (Kirsch, Jungeblut, Jenkins, & Kolstad,

[1] Numeracy, quantitative literacy (QL), and quantitative reasoning (QR) are referenced in the literature. Definitions provided for these terms differ slightly among authors, so no consensus has been reached as to how to define them. I do not choose to focus on the differences in nuance between the terms and among authors. My focus is on the common elements to which the terms refer. Hence, I use the three terms interchangeably.

1993).[2] Though definitions of QL vary, the skills to which they refer share common elements—specifically, the ability to apply basic computations to numbers in context and a disposition to reason with data and think logically to make decisions (Steen, 2001b). As Paulos' (1988) many examples show, innumeracy increases gullibility and inhibits rational decision making. A decade after Paulos' book was published, QL was essentially presented to the mathematics education community as an antidote to the innumeracy of which he wrote (Orrill, 2001).

Statement of the Problem

American college graduates lack quantitative literacy. According to employers, prospective employees too often do not have adequate quantitative skills and are innumerate (Rosen, Weil, & Von Zastrow, 2003; Steen, 1999). In a study conducted by the Program for the International Assessment for Adult Competencies, only 18% of bachelor's degree holders between 16 and 65 years of age demonstrated proficiency with numeracy using an assessment that measured real-world mathematical skills. This put the United States below the international average of 24% (Goodman, Finnegan, Mohadjer, Krenzke, & Hogan, 2013). Roohr, Graf, and Liu (2014) reported that 34% of 2-year college students and 24% of 4-year college students who graduated between 2009 and 2012 self-identified as being underprepared to use quantitative reasoning skills. They further indicated that only around 50% of 4-year students demonstrated QL as defined above (Roohr et al., 2014). In short, U.S. colleges and universities need to improve their students' QL outcomes.

One reason for American graduates' low QL is that many colleges do not teach it to students as part of their curricula. When it is taught, it is often added as a component within a math course (Williams, 2016). Educators mistakenly believe that QL is synonymous with

[2] The other two types of literacy are prose literacy and document literacy.

mathematics when it is, in fact, distinct. Mathematical skills such as arithmetic, percentages, ratios, simple algebra, measurement, estimation, logic, data analysis, and geometric reasoning are all included in QL, but these simply form the mathematical basis; QL goes beyond, situating mathematical content in real-world contexts, providing skills and knowledge that are needed to function in a society faced with ever increasing amounts of data (Steen, 2003). Prescriptive literature indicates that a more appropriate approach to teaching QL is to embed it in courses across the curriculum (e.g., Gillman, 2006; Steen, 2001b). By so doing, educators can better help students make connections between quantitative content and their everyday lives.

Using a case study design, the current research examines the process of integrating quantitative content into community college courses. I draw upon interviews and document analysis to identify obstacles to and supports for implementing QL across the curriculum on community college campuses and, as appropriate, to understand how these obstacles have been overcome. Among these obstacles is what some educators have come to view as a legacy requirement of algebra for all students (Carnevale & Desrochers, 2003; Steen, 2001a).

Background

The Quantitative Literacy Movement in the 21st Century

In 2001, the National Council on Education and the Disciplines (NCED) published *Mathematics and Democracy: The Case for Quantitative Literacy*, a collection of essays edited by Lynn Arthur Steen, the former president of the Mathematical Association of America (MAA). This work marked the beginning of a national focus on QL (Ward, Schneider, & Kiper, 2011). Subsequently, MAA, together with NCED and the Mathematical Sciences Education Board held a forum focused on QL education. The proceedings of the forum were documented in *Quantitative Literacy: Why Numeracy Matters for Schools and Colleges* (2003), edited by Steen and Madison, which was later refined to form *Achieving Quantitative Literacy: An Urgent Challenge for Higher Education* (2004), edited by Steen. In 2006, the American Mathematical Association of Two-Year Colleges (AMATYC) published *Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College*, which also includes a QL focus. Thus, the mathematics education community began this century by shining a spotlight on quantitative literacy.

Concurrent with the early works noted above, QL proponents founded the National Numeracy Network (NNN), modeling it loosely after the National Writing Project. The stated goal of NNN is essentially to promote numeracy education and understanding (Madison & Steen, 2007). In 2008, NNN published the first edition of its online journal *Numeracy: Advancing Education in Quantitative Literacy*—a multidiscipline, peer-reviewed publication that serves as a resource for administrators, educators, and researchers whose interests include improving QL education in the United States (Vacher & Wallace, 2013).

The above volumes present various definitions of QL and related concepts like numeracy and quantitative reasoning. They also emphasize that QL is not solely the responsibility of math faculty. While math educators can and should lead the charge in implementing QL curricula on their campuses, one of the defining characteristics of QL is that it is contextualized. As such, it should be incorporated into courses across the curriculum in a multidisciplinary approach (Blair, 2006; Richardson & McCallum, 2003; Steen, 2001a). Despite the value and increasing awareness of QL, there are barriers to infusing it into the community college curriculum.

A Curricular Barrier to Quantitative Literacy

For the last half of the 20th century, mathematical education was dominated by a focus on preparing students for calculus. The successful launch of Sputnik in 1957 sparked interest in mathematics education at the national level. The priority at the time was to increase the number of mathematicians and scientists so the United States could better compete on a global scale (Chesky, 2013; Greer, 2008; Madison & Steen, 2003; Proctor, 2011; Root, 2009). The result of the reforms of the 20th century was an algebra-for-all paradigm. We now have high-stakes, standardized tests in K–12, and college entrance exams that emphasize the algorithmic approaches used in algebra (Ewell, 2001; Kennedy, 2001). The narrow focus of the discipline of mathematics has come at the expense of QL and has led to poor outcomes for many students (Attewell, Lavin, Domina, & Levey, 2006; Bahr, 2008; T. Bailey, 2009; Gaze, 2014).

Differences Between Quantitative Literacy and Mathematics

Quantitative literacy is easier to describe than to define (Gillman, 2006; Steen, 2001a), though Richardson and McCallum (2003) presented a definition of a quantitatively literate person that parallels an accepted definition for prose literacy: "A quantitatively literate person is a person who, with understanding, can both read and represent quantitative information arising in his or her everyday life" (p. 99). QL is best realized when embedded in non-math courses, because too often mathematics instruction is decontextualized. Math in traditional math courses consists of algorithmic processes that students try to master but that do not teach them how to approach novel problems. Algebra, as it is taught in schools and colleges does not lead to a numerate society (Carnevale & Desrochers, 2003); it is part of a hierarchical structure that leads to ever more abstraction that becomes increasingly difficult to connect to everyday life. By contrast, QL has direct connections with the kind of mathematical concepts and numerical data that appear in the media, that consumers need to make informed decisions, and that lead to the ability to think critically about politics and legislation (Paulos, 1988). Table 1, created by Shavelson (2008), indicates some differences between mathematics and quantitative reasoning.

Table 1

Mathematics versus Quantitative Reasoning

Mathematics	**Quantitative Reasoning**
Power in abstraction	Real, authentic contexts
Power in generality	Specific, particular applications
Some context dependency	Heavy context dependency
Society independent	Society dependent
Apolitical	Political
Methods and algorithms	Ad hoc methods
Well-defined problems	Ill-defined problems
Approximation	Estimation is critical
Heavily disciplinary	Interdisciplinary
Problem solutions	Problem descriptions
Few opportunities to practice outside the classroom	Many practice opportunities outside the classroom
Predictable	Unpredictable

Source: Shavelson (2008)

Existing Studies on Quantitative Literacy

A comprehensive search of the literature revealed 24 empirical studies focused on QL in higher education settings. Of these, 13 involved participants at 4-year schools, seven involved only individuals at community colleges, and four involved a mix of university and community colleges or did not explicitly specify the setting. The bulk of the studies focused on assessing QL, curriculum redesign (typically with algebra courses), beliefs of math faculty regarding curriculum, and student QL outcomes.[3] One study (Jorgensen, 2014) examined obstacles faced by faculty who were involved in curricular redesign; this was at a university, and among the barriers was the impact of offering advanced math degrees, an issue not present on community college campuses. I have not found any studies documenting obstacles faced by community

[3] Chapter 2 contains a more detailed description of the studies.

college personnel who have implemented QL using a multidisciplinary approach. Thus, the current study fills a gap in the existing research.

Project Statement and Research Questions

The goal of this study was to identify supports and obstacles to implementing QL across the community college curriculum and how they have been handled. Publications by MAA and AMATYC have made clear the need for incorporating QL instruction across the educational spectrum and across the curriculum. Some progress has been made since the start of the 21st century, but a lot of work remains.

One step toward increasing QL in society is to increase it in higher education. As Vacher and Wallace (2013) and Steen (2004) indicated, an across-the-curriculum approach to QL instruction is the responsibility of faculty both in and outside of math departments, as well as administrators, all of whom must address the challenges of broad curricular change. For institutions wishing to embed QL across the curriculum, the journey has challenges. Recognizing this, some researchers have drawn from lessons learned from movements that have resulted in writing across the curriculum. Hillyard (2012) compared the two movements and identified challenges common to both including institutional buy-in, assessment, student resistance, and funding.

The effort of one community college, Edmonds Community College (EdCC), to satisfy an institution-level quantitative reasoning student learning outcome eventually grew into a national professional development network, Mathematics Across the Community College Curriculum (MAC^3). Affiliated with AMATYC, MAC^3 supported community college faculty in designing and implementing interdisciplinary mathematics curriculum. It was in place from 2005 to 2010, while it was supported by a grant from the Natural Science Foundation. The primary focus of this study is the MAC^3 program and its participants as they sought to implement interdisciplinary QL. To that end, the study sought to answer the following research questions:

1. To what extent were faculty able to implement interdisciplinary QL on their community college campuses?
    a. What factors supported implementation?
    b. What factors limited implementation?
2. What were the successes of and obstacles faced by the MAC^3 program?

As indicated in the literature review in the next chapter, leadership plays a crucial role in interdisciplinary efforts on college campuses, including community colleges. So while leadership was not explicitly referenced in the research questions, it was assumed that leadership would be an emergent theme in the findings. As such, the role of leadership in interdisciplinary initiatives is also examined in Chapter 2.

Methods

Site and Population

I examined the process of implementing QL across the community college curriculum, the obstacles faced by community college personnel in doing so, and (where applicable) how these obstacles were overcome. *Site* has two meanings in this study. One is the nonphysical "site" of MAC^3. "Site" also refers to several community colleges at which the directors and participants of MAC^3 worked when they created and implemented their QL projects. Study participants were faculty members who created and participated in MAC^3, as well as some of their colleagues at EdCC.

Research Design

I conducted a qualitative case study. I interviewed MAC^3 directors and participants as well as several additional EdCC faculty members who had undertaken QL work. The case study also included document and website analysis. The focus of the interviews was the motivation and experiences of faculty who incorporated QL into their non-math classes, the obstacles they faced, and their successful strategies for overcoming those obstacles. Through interviews, I was able to gather rich data about participants' lived experiences in establishing embedded QL (Merriam & Tisdell, 2016). Further, document and website analysis allowed for triangulation and for the rich description characteristic of a case study. Since I asked participants about what they experienced, the findings have practical significance for others who desire to embed QL on their campuses.

Significance of the Research

Significance of the Study

This study was designed inform those who wish to undertake multidisciplinary QL work on community college campuses. Community colleges fill a unique need in higher education. As open-access institutions, they do not exclude any student based on prior academic preparation. Some students enroll to bridge the gap between high school and universities; others have alternative educational goals that are served by the community college curriculum (Goldrick-Rab, 2010). If we can increase QL on community college campuses, more students will develop the skills they need to be informed citizens and consumers. By learning how others have managed the challenges of initiating and sustaining QL in community colleges, educators will be better equipped to better meet society's needs, and students will be more able to succeed in 21st century environments.

This study has the potential for widespread significance. Hillyard (2010) wrote of some anticipated difficulties in implementing QL across the curriculum, but prior to the current study there had not been empirical work that examined the obstacles community college faculty and administrators face and how these obstacles have been overcome. California alone has 113 community colleges. While some may have implemented QL across the curriculum, it is likely that many have not. For those wishing to do so, being aware of potential obstacles they will face and how they have been overcome will be instrumental for effective implementation. Thus, the results of this study will be of use to community college faculty and administrators who are committed to infusing QL across their curricula.

Public Engagement

The results of the current study add to the existing literature regarding QL in higher education. I plan to distribute a modified form of this study to national networks such as AMATYC and NNN, for example as a presentation at the AMATYC annual conference. NNN can potentially include it on their open-access journal, *Numeracy*. Locally, I will share my findings at my own site, Pasadena City College, as well as my colleagues' network of Southern California community college educators who attend "un-conferences"—informal gatherings where faculty meet to share ideas and best practices.

Chapter Two:

Literature Review

For some in the mathematics education community, calculus remains the goal of undergraduate math. Others perceive this focus as due to an overinflated sense of the importance of both algebra and calculus for non-math and non-science majors (Hacker, 2016). During the Space Race, the federal government pressured colleges and universities to produce more scientists and engineers, but this was at the expense of teaching practical numeracy to the majority of students. Most students would better benefit from quantitative literacy, which encompasses various skills that are based on basic mathematics but that extend well beyond the hierarchical, abstract mathematics to which students are subjected by the traditional curriculum.

As a remedy to this situation, the QL movement has gained momentum since the beginning of the new millennium. As Elrod (2014) indicated, the Association of American Colleges and Universities (AAC&U) and the Western Association of Schools and Colleges (WASC), the accrediting body for higher education in the western United States, have recently emphasized quantitative reasoning and QL as core skills in higher education. Increasing numbers of colleges and universities are trying to find ways to satisfy QL requirements (Ward et al., 2011). They are doing so in the form of standalone QL courses and, in some cases, by infusing QL across the curriculum. A review of the literature sets the stage for this study, through both historical background and a summary of the state of QL on college campuses today.

I begin the literature review by defining quantitative literacy, and I then present evidence that QL needs to be improved in U.S. adults. Next, I describe some of the benefits and uses of QL in various arenas. Having introduced QL, I describe its roots as well as the modern QL movement in U.S. higher education, including various QL efforts in higher education institutions today. I include a brief description of MAC[3], which is the focus of the current study.

Definitions of Quantitative Literacy

Many authors consider *numeracy*, *quantitative literacy*, and *quantitative reasoning* to be synonymous, though some make distinctions between the terms. The purpose of this study is to identify strategies for implementing QL across the community college curriculum rather than to distinguish nuance between terms. As such, this section is inclusive with respect to definitions relating to QL. In this section I provide definitions from the QL literature, described chronologically.

Numeracy

According to Cockcroft (1982), the term *numeracy* first appeared in The Crowther Report, an advisory report prepared by England's Ministry of Education. Crowther (1959) introduced numeracy and drew parallels to literacy. In another government report two decades later, Cockcroft (1982) described numeracy as an "'at-homeness' with numbers" and "an ability to have some appreciation and understanding of information which is presented in mathematical terms, for instance in graphs, charts or tables or by reference to percentage increase or decrease" (p. 11). Later that decade, John Paulos (1988) popularized and defined *innumeracy* in his bestselling book of the same name as an "inability to deal comfortably with the fundamental notions of number and chance" (p. 3). While the literature makes some references to *numeracy*, authors in the United States more commonly refer to *quantitative literacy*.

Quantitative Literacy

In more of a description than a definition, the MAA's Committee on the Undergraduate Program in Mathematics (Sons, 1994) presented QL as follows:

> In short, every college graduate should be able to apply simple mathematical methods to the solution of real-world problems. A quantitatively literate college graduate should be able to:
>
> 1. Interpret mathematical models such as formulas, graphs, tables, and schematics, and draw inferences from them.
> 2. Represent mathematical information symbolically, visually, numerically, and verbally.
> 3. Use arithmetical, algebraic, geometric and statistical methods to solve problems.
> 4. Estimate and check answers to mathematical problems in order to determine reasonableness, identify alternatives, and select optimal results.
> 5. Recognize that mathematical and statistical methods have limits. (Part II, para. 6)

For the National Adult Literacy Survey administered in 1992, the U.S. Department of Education defined three literacies: prose, document, and quantitative. The definitions of document literacy and quantitative literacy each contribute to the current notion of quantitative literacy (Steen, 2004). Document literacy was defined as

> …the knowledge and skills required to locate and use information contained in materials that include job applications, payroll forms, transportation schedules, maps, tables and graphs; for example, locating a particular intersection on a street map, using a schedule to choose the appropriate bus, or entering information on an application form. (Kirsch et al., 1993, p. 3)

Quantitative literacy was defined as

> …the knowledge and skills required to apply arithmetic operations, either alone or sequentially, using numbers embedded in printed materials; for example, balancing a checkbook, figuring out a tip, completing an order form, or determining the amount of interest from a loan advertisement. (Kirsch et al., 1993, pp. 3–4)

In 1997, John A. Dossey, as former president of the National Council of Teachers of Mathematics (NCTM), defined quantitative literacy in terms of ability to “interpret and apply [specific] aspects of mathematics to fruitfully understand, predict, and control relevant factors in a variety of contexts” (pp. 173–174). These specific aspects were data representation and interpretation, number and operation sense, measurement, variables and relations, geometric shapes and spatial visualization, and chance.

Finally, the AAC&U (2009) created a rubric for use by higher education institutions that wished to assess QL. The rubric contained the following definition:

> Quantitative Literacy (QL)—also known as Numeracy or Quantitative Reasoning (QR)—is a “habit of mind,” competency, and comfort in working with numerical data. Individuals with strong QL skills possess the ability to reason and solve quantitative problems from a wide array of authentic contexts and everyday life situations. They understand and can create sophisticated arguments supported by quantitative evidence and they can clearly communicate those arguments in a variety of formats (using words, tables, graphs, mathematical equations, etc., as appropriate).

Lynn Arthur Steen, former president of MAA, captured the essence of quantitative literacy when he described “the use of mathematics in everyday life and its applications to other subjects” (Steen, 1997a, p. xxi). While it is clear that there are differences in how QL is described, there is agreement on how it is enacted. As this study focused on QL in community colleges, I relied on the ACC&U (2009) definition quoted above. Next, I present several metrics that indicate that Americans lack QL.

American Adults Lack Quantitative Literacy

American adults do not have the QL skills needed in today’s data-drenched (Steen, 1999), technology-driven society. As the literature shows, this has been a trend for over two decades. I summarize these findings in this section.

National and International Literacy Assessments

Kirsch et al. (1993) reported the results of the 1992 National Adult Literacy Survey. Participants were randomly selected and representative of the population. Results were reported by level, with Level 1 being the lowest and Level 5 the highest. An example of a Level 2 document literacy task was to find the year-to-date gross pay on a paystub; a Level 2 QL task asked respondents to determine the difference between two stated prices. Note that these two types of literacy constitute QL as it is used in the higher education literature.

The study found that only 18% and 21% of participants performed at the highest two levels of document and QL, respectively. In contrast, 51% of participants performed at the two lowest levels for document literacy, and 47% were at the lowest two levels for QL. Those scoring at these two levels represented roughly 90 million adults. Of note is that the adults who scored at the lowest two levels indicated that they were able to function without deficiency in their day-to-day lives. This is despite the reality that those in this group were less likely than those in the higher levels to vote or hold full-time jobs (Kirsch et al., 1993).

An International Adult Literacy Survey, conducted in 1994, used the same literacy definitions as the 1992 survey and yielded comparable results by level. Eight countries participated in 1994: Canada, Germany, Netherlands, Poland, Sweden, Switzerland, and the United States. The only country with a higher proportion of adults at Levels 1 and 2 than the United States was Poland. This study again noted a relationship between literacy and income/employment (Organisation for Economic Co-operation and Development & Statistics Canada, 1995).

Another more recent international survey, the Program for the International Assessment of Adult Competencies, was conducted in 2011–2012 with a nationally representative sample of 5,000 adult Americans; in all, 23 countries participated. The quantitative measure was termed *numeracy* and defined as “the ability to access, use, interpret, and communicate mathematical information and ideas, to engage in and manage mathematical demands of a range of situations in adult life” (Goodman et al., 2013, p. 2). The reader will note the similarity between this definition and those for QL. Thirty percent of U.S. adults performed at Level 1 or Level 2; one other country (Italy) had a higher proportion at these levels (Goodman et al., 2013).

It is important to point out that St. Clair (2012) has critiqued both the methods and presentation of the international surveys. He cautioned against broad comparisons between countries or over time, although he seemed to support their use in comparing, for instance, gender performance in various countries. Nonetheless, as I discuss next, U.S. employers lament the lack of numeracy in the workforce.

Quantitative Literacy in the Workforce

Modern businesses rely on technical communication, statistical, and computer skills—skills in which they find employees lacking (Steen, 1999). Rosen, Weil, and Von Zastrow (2003) cited a 2001 survey in which more than one-quarter of job applicants who took basic skills tests for potential employers did not have the skills necessary for managing spreadsheets and databases. According to a report by the Brookings Institution (Goldberg, Traiman, Molnar, & Stevens, 2001), projections for 2006 included that only 20% of the then-current workforce possessed the appropriate skills for 60% of all new jobs. QL gives people the kinds of transferrable skills necessary in a changing workforce landscape. Other indications point to college graduates' lack of facility with numbers (Ball, 2003). Finally, in a summary of the state of assessments of QL in higher education, Roohr, Graf, and Liu (2014) cited several studies indicating that one-fourth to one-third of college graduates self-reported feeling underprepared to use QL, and only about half of college seniors and freshman drew their own conclusions based on numerical information. Predictably, the trend was that those in non-STEM majors did so less than STEM majors. These numbers speak to a prevalence of deficient QL. To clarify how this impacts individuals, I now turn to the benefits of QL in our daily lives.

Benefits and Uses of Quantitative Literacy

QL, as indicated by its definitions and descriptions, encompasses a variety of skills as well as a habit of mind. This section shows the benefits and uses of QL in various areas of life. Some examples are so ubiquitous as to be almost invisible, such as baseball players' batting averages or a weather forecast indicating the percentage chance of rain. Others are subtle—for instance, knowing the kinds of problems that can be solved with mathematics and statistics, the kinds of answers they can provide, and when such techniques do not apply (Lott, 2003; Niss, 2003; Steen, 2001b).

Properly applied, the skills required for QL extend beyond mathematics into reasoning and logic of the type required to follow or construct an argument. Further, given the amount of information available today to anyone with a computer and an internet connection, the ability to manage and analyze data is a 21st-century QL skill (Brakke, 2003; D'Ambrosio, 2003). The need for QL manifests itself in different ways in education, in the workplace, in people's personal lives, and in the responsibilities imputed to informed citizens. I address each arena in turn.

Education

One of the most obvious places individuals use mathematical reasoning is in college courses. It is well known that mathematics forms the basis of disciplines like physics, computer science, and engineering. Perhaps less obvious is the need to be able to manage data and computers in, for example, biology. Biologists now use computer modeling and require computational skills. With the advent of computer graphics, graphic arts majors need to work with computer algorithms, the logic for which is based in mathematics. Social scientists are heavily dependent on statistics, and the scientific nature of psychology requires QL (Brakke, 2003; Steen, 2001b). Of course, the need for QL does not diminish after graduation, as workers face QL challenges on a daily basis.

Workplace

In today's offices, workers need to be proficient with spreadsheets and to read charts, tables, and graphs. The former requires the ability to enter formulas and manipulate data; the latter contributes to document literacy, a component of QL. Office managers need to be able to analyze profits and losses; at times, even scheduling employees requires creative problem solving abilities. Lawyers rely on argumentation skills, which are logical structures that are sometimes abstract, at other times quite concrete. Lawyers also appeal to notions of probability in their efforts to sway jurors (De Lange, 2003; Steen, 2001b; Usiskin, 2001).

Numerical sense is required of both managers and laborers at the negotiating table. Public servants need to understand the laws that affect their service and should be able to communicate relevant information to those they serve. Quantitative skills are essential for health care workers in managing patient care, from correctly computing and measuring doses of medication to communicating the risks and benefits of medical care to their patients (Packer, 2003; Rosen, 2001; Steen, 2001b). These are but a few examples of how QL is used on the job; the reader likely has other examples as well. Were the need for QL limited to work and school, it might be argued that it is of limited benefit, but further examples exist in our personal lives.

Personal Utility

Perhaps the easiest case to make for QL relates to personal finance. Understanding taxes (or even tax forms), making an informed decision about whether to buy or lease a car, and planning well for retirement all require numeracy. Understanding and negotiating a contractor's bid on a homeowner's renovation project or how credit card interest works can lead to more sound financial decisions. Other areas of intersection between QL and our personal lives exist in health care decisions. However well informed one's doctor might be, the patient needs an understanding of statistics to interpret the results of clinical trials or to understand the risks of a particular medication. Selecting a healthcare plan has both financial and health implications; understanding such plans requires all three forms of literacy—document, quantitative, and prose (De Lange, 2003; Orrill, 2001; Packer, 2003; Steen, 2001b).

Planning for a vacation and making sense of nutrition labels both require number sense and document literacy. Quantitative material is ubiquitous in newspapers. Having a sense of geometry and problem solving skills can help optimize the layout of furniture in a room. Ultimately, QL improves critical thinking skills. These are the skills that guard against gullibility and underlie the ability to ask insightful and intelligent questions when appropriate (Packer, 2003; Steen, 2001b; Usiskin, 2001).

Citizenship

Effective democracy is contingent upon an informed citizenry. Analyzing voter information guides, public debates on policy issues, voting patterns, and even acts of congress all require various aspects of quantitative literacy, as does the ability to confidently confront authority and intelligently question experts. Understanding how tax breaks affect the federal deficit and what the future may hold for Social Security funding are key issues that are affected in the voting booth. Properly fulfilling one's civic duty in the jury box requires an understanding of probability arguments prosecuting or defense attorneys might put forth. It is also important that decisions that should be made based on logic are not swayed by emotional arguments; the quantitatively literate citizen recognizes the difference (P.C. Cohen, 2001; Orrill, 2001; Steen, 2001b). Ignorance in these areas can lead to poor decisions with widespread and profound implications. By ensuring that students learn QL, we are investing in their future as consumers as well as in our own future, in the workforce, and in our society.

Growth of Quantitative Literacy Efforts in Higher Education

Several movements in the 20th century influenced what math was taught in K–12 classrooms and how it was taught. While schools engaged in the new math, the math wars, and back-to-basics, colleges remained mostly autonomous to develop their own standards. They were not, however, exempt from recommendations. Bodies that have shaped the college math landscape are the MAA's standing Committee on the Undergraduate Program in Mathematics (CUPM), AMATYC, and the National Council of Teachers of Mathematics (NCTM). CUPM and AMATYC make direct recommendations to the higher education community. NCTM mainly focuses on K–12 mathematics education, though the organization partners with MAA through a joint committee, and their publications influence mathematics education at all levels.

Attempts at Mathematics for General Education

In 1953, MAA, referred to as "the national professional organization concerned with the teaching of mathematics at the college level" (CUPM, 1969, p. 208), formed a standing Committee on the Undergraduate Program in Mathematics, initially called CUP, and later reformed and renamed CUPM. ("Program" referred to various components of the educational system.) From 1954 to 1958, CUPM developed and piloted a universal mathematics course with a goal of providing students adequate mathematics preparation, regardless of their educational goals. The universal course was designed to serve a liberal arts education, and although the universal course included basic calculus, the idea that not all students needed the same mathematical preparation was made clear by CUPM's recommendation (Sons, 1994; Steen, n.d.). This idea was soon set aside.

Shortly before the end of the pilot, the world saw the successful launch of Sputnik, and the mathematics education community was pressured by the federal government to produce more scientists and engineers (L. J. Bailey & Stadt, 1973). During the two decades that followed, CUPM focused mostly on the training of mathematics teachers, 4-year college transfer programs in community colleges, and mathematical needs relating to the rise of computers. During the late 1960s, CUPM created panels focused on general education mathematics, technical-occupational mathematics, and mathematics for 4-year transfer students of all disciplines. Though 2-year college teachers expressed the need for guidance with general education and technical-occupational mathematics, CUPM determined that it was natural and logical to focus on the 4-year transfer track. In 1969, the committee released *A Transfer Curriculum in Mathematics for Two-Year Colleges*. Steen (n.d.) cited a lack of funds as the reason the general and technical tracks were not further developed. Thus, the idea of developing alternative math curricula for non-STEM majors was set aside for reasons financial and global.

Initial Quantitative Literacy Recommendations

In 1978, CUPM formed a subcommittee to consider QL, though at the time it was not a main focus (Sons, 1994; Steen, n.d.). Shortly after the committee was formed, NCTM published *An Agenda for Action: Recommendations for School Mathematics of the 1980s*. Recommendations in *An Agenda for Action*, published in 1980, include diversifying K–12 mathematics and teaching QL as part of consumer math. Recommendations included that educators and college personnel reconsider the role of calculus in math education (National Council of Teachers of Mathematics, 1980). Hence, mathematics curriculum discussions were beginning to include QL, though, as later publications indicate, the concept was still not finding traction.

QL received more attention at the end of that decade. In 1989, MAA formed a subcommittee to consider QL requirements for college graduates (Sons, 1994). In that same year, NCTM published *Curriculum and Evaluation Standards for School Mathematics* (the *Standards*). The MAA committee later published a report, *Quantitative Reasoning for College Graduates: A Complement to the Standards* (1994), applying the *Standards* to higher education.

Though the *Standards* were written for K–12 educators, Prichard (1995) considered the implications if they were applied to community colleges. What he described holds strong similarities to the suggestions made by QL proponents. Prichard posited that NCTM's curricular reform goal of all students being mathematically literate would require a realignment of college mathematics courses, which were designed as preparation for calculus or college algebra. He described undergraduate mathematics education through the lens of a laboratory discipline and indicated that applying NCTM's recommendations for reform, in particular its focus on real-world problem solving, had relevance for the community college's role of educating the workforce.

Quantitative Literacy Recommendations for Higher Education

Prichard's (1995) work with the *Standards* was a thought experiment. AMATYC went further and built on the original *Standards* document in *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus*, written in 1995 for mathematics educators at 2-year colleges. The standards set forth in *Crossroads* were the first that specifically targeted curricula for students whose educational and career goals did not include calculus (D. Cohen, 1995). Thus, 40 years after CUPM's *Universal Math Course*, math for non-STEM majors was being considered on the national stage. In *Crossroads*, AMATYC indicated that it was not appropriate to prescribe curricula for liberal arts majors. The work did, however, indicate that the traditional curriculum found in college algebra and calculus courses was not broad enough for non-STEM majors (D. Cohen, 1995).

Following *Crossroads,* Lynn Arthur Steen, then-former president of MAA, edited and authored a series of works, including *Why Numbers Count* (1997b), *Mathematics and Democracy* (2001a), *Quantitative Literacy: Why Numeracy Matters for Schools and Colleges* (2003) (with Bernard Madison), and *Achieving Quantitative Literacy: An Urgent Challenge for Higher Education* (2004). Whether because of his work with MAA or because of these publications, Steen is considered to be one of the founders of the QL movement (Ward et al., 2011). Steen has referred to *Mathematics and Democracy* as the "starting point" for "a national examination of issues surrounding QL, especially in the context of school and college studies" (Steen, 2004, p. xi).

After the flurry of Steen works, in 2006 AMATYC published a follow-up to *Crossroads*, called *Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College.* Both *Crossroads* and *Beyond Crossroads* were endorsed by, among other groups, MAA and NCTM (Blair, 2006; D. Cohen, 1995). *Beyond Crossroads* explicitly stated that developing QL is the responsibility of faculty across the college campus, and it compared QL to writing across the curriculum.

Quantitative Literacy Practices in Higher Education

Following the QL recommendations from AMATYC and MAA, colleges and universities worked to incorporate QL into their curricula (Ward et al., 2011). That this became a national focus is evidenced by the fact that the AAC&U included QL in its essential learning outcomes, to be "practiced extensively, across the curriculum" (National Leadership Council for Liberal Education and America's Promise, 2007, p. 3). In this section, I present a summary of prior research on QL and then outline the ways colleges and universities have chosen to satisfy QL outcomes, in order of increasing effectiveness.

Existing Studies on Quantitative Literacy

To find existing studies on QL, I searched EBSCOhost, ERIC, and ProQuest for the following terms: “quantitative literacy,” “quantitative reasoning,” and “numeracy.” I paired each of these terms with “college,” “community college,” and “higher education” to identify publications of interest. I searched within the text of the resulting documents for keywords that would be included in a study. The search terms I used were “methods,” “findings,” “results,” “analysis,” and “conclusions.” The search revealed a total of 24 studies relating to QL in higher education. In Table 2, the numerals in parentheses give the number of indicated studies. As shown, none of these studies examined barriers to implementing QL across the curriculum at a community college. Thus, the current study fills a gap in the literature.

Table 2

Types of Higher Education QL Studies

	University/ 4-year (n = 13)	**Community College (n = 7)**	**Higher Education (unspecified or both) (n = 4)**
Quantitative (n = 14)	*Assessment development (n = 2) *Student QL outcomes/ attitudes/perceptions (n = 5) *Curricular focus (n = 2)	*Student attitudes (n = 2) *Assessment and outcomes (n = 2)	*Improving assessment (n = 1)
Qualitative (n = 7)	*Barriers to curricular change (n = 1) *Student behaviors and engagement in a QL course (n = 1) *Developing QL at small colleges and universities (n = 1)	*Faculty beliefs regarding curriculum (n = 2)	*SSAC modules (n = 1) *Instructor attitudes regarding Quantway (n = 1)
Mixed Methods (n = 3)	*SSAC modules (n = 1)	*Implementation of “StatMode,” a pseudonym (n = 1)	*Educator beliefs regarding curriculum (n = 1)

Quantitative Literacy and Mathematics Courses

Some institutions have elected to fulfill QL requirements by using existing traditional algebra courses (Roohr et al., 2014). While keeping the letter of the law, so to speak, this strategy misses its spirit. As the literature indicates, QL is not achieved in a one-semester class, and algebra is a poor venue for QL. In particular, studies have shown that when traditional (algebra and calculus) math courses are compared to dedicated QL courses, math courses are not sufficient substitutes; QL outcomes are better in dedicated QL courses (Agustin, Agustin, Brunkow, & Thomas, 2012; Todd & Wagaman, 2015). This could be because algebra is part of an increasingly abstract hierarchy designed to prepare students for calculus, which 85–95% of students do not need to take (Carnevale & Desrochers, 2003; Gaze, 2014; Gordon, 2008; Herriott & Dunbar, 2009). QL, on the other hand, is a mindset and a broad set of abilities that puts math to practical use.

Other strategies have been to incorporate QL into existing math courses, such as college algebra; Small (2006) noted that this is better than simply using the algebra curriculum, but it has some of the same shortcomings described above. Students who take such courses may end up doing better in algebra but still develop only limited QL skills. As Gaze (2014) indicated, QL can provide a good foundation for algebra, though in an algebra class it would have limited contextualization, as it would remain contained within the mathematics discipline.

A third strategy is to develop one or more QL courses—interdisciplinary courses designed to imbue students with QL. This approach does not limit content to mathematics and therefore has more opportunities for contextualization than exist in a math course. Further, students who take such courses have been shown to have better QL outcomes including writing skills, improved attitudes toward real-world applications, increased confidence in their mathematical abilities, and decreased anxiety levels toward math (Grawe, 2013; Scherger, 2013; Todd & Wagaman, 2015; Van Peursem, Keller, Pietrzak, Wagner, & Bennett, 2012; Wismath & Worrall, 2015).

The Carnegie Foundation's Statway and Quantway are examples of dedicated QL pathways. Statway is a one-semester course that addresses developmental math and statistics so that college students can meet their college-level math requirements in one semester. Quantway is a two-semester sequence that allows students to earn college-level math credit in one year. These courses allow non-STEM students the opportunity to bypass traditional developmental sequences of math–algebra–statistics/college algebra that may take up to two years to complete (Clyburn, 2013). Though students in these pathways have higher success rates than those in traditional developmental math courses do, the reader is reminded that the recommendations in the previous section indicate that QL should be infused across the curriculum.

Interdisciplinary Quantitative Literacy

Interdisciplinary QL, the focus of the current study, involves embedding QL in multiple courses across the curriculum. This has been done in some community colleges through MAC^3, as presented by Hillyard, Korey, Leoni, and Hartzler (2010). MAC^3 was a national initiative that offered faculty participants the opportunity to attend workshops and develop curricula for use in paired courses—for instance, an art class paired with a math class. AMATYC's journal, *MathAMATYC Educator*, published a special issue focused on MAC^3 (Korey & Hillyard, 2010). Faculty in community colleges described their experiences and projects with paired classes and learning communities using curricula that they developed with the support of MAC^3. Because the projects were faculty-developed, rather than administrative initiatives, they were grassroots efforts. By definition, grassroots leaders do not have authority to make institutional change

(Kezar & Lester, 2011). As of 2010, the year of the most recent MAC[3] report, faculty teams from 36 colleges had participated in the initiative (Gilliland, 2010).

Another such embodiment is Spreadsheets Across the Curriculum (SSAC), another grassroots effort for the spread of QL (Vacher & Lardner, 2010). The basis of SSAC is a set of spreadsheet modules used for teaching numeracy in a variety of courses in secondary schools and higher education. As of 2010, over 100 modules had been disseminated and used by 80 higher education institutions; only nine had been requested by community college faculty. Considering the overall numbers of these two initiatives and the fact that there are 113 community colleges in California alone (California Community Colleges Chancellor's Office, 2017), much work remains, a fact punctuated by the title of a recent AAC&U article, *Quantitative Reasoning: The Next "Across the Curriculum" Movement* (Elrod, 2014).

Obstacles to Interdisciplinary Quantitative Literacy Instruction

Obstacles to implementing curricular reform and interdisciplinary efforts can take many forms. Some that I describe below apply to institutional and curricular change generally, while others are specific to implementing QL instruction. As no empirical studies exist regarding obstacles to implementing QL on community college campuses, this study sought to identify such obstacles. I anticipated at least some alignment between the obstacles listed below and the findings of the current study.

Institution-Level Obstacles

Obstacles related to interdisciplinary work include the siloed nature and specialized curricula on college campuses, the difficulty finding time and willing faculty for collaboration, turf wars, and departmental resistance to administrative efforts to implement institutional goals (Carnevale & Desrochers, 2003; Hillyard et al., 2010; Hughes-Halett, 2001; Kim & Stabley, 2010; Rogotzke, Zoellner, Larson, & Fallis, 2010; Seymour, 2002). Embedding QL across a campus requires interdisciplinary dialogue, and some teachers may not want to give up class time to incorporate additional content (Hughes-Halett, 2001; Leoni & Hartzler, 2010). Further, it is difficult for change in one department to spread to other departments (Seymour, 2002), owing at least in part to the loose coupling (addressed in the next section) that characterizes community college campuses.

Generating buy-in can be difficult because of a low level of public concern regarding QL (Steen, 2001a). Unsupportive administrators have been identified as barriers to interdisciplinary efforts, particularly on community college campuses (Korey, 2010; Leoni & Hartzler, 2010). Eager faculty returned to their campuses from professional development workshops to find that administrators were skeptical or not willing to help them implement what they had developed. QL presents a challenge to support staff and advisors because the lack of a common definition for the concept makes it difficult to understand and explain (Todd & Wagaman, 2015).

Assessment can also be difficult; it is challenging to know what to assess regarding QL, and how best to approach assessment is not always clear (Berg et al., 2014; Bookman, Ganter, & Morgan, 2008; Ewell, 2001; Grawe, 2011; Hubert & Lewis, 2014; Roohr et al., 2014). While this does not speak directly to implementation, if a college cannot assess QL and thereby identify its students' lack of QL, then the institution will not see the need to teach it. A related difficulty is that if QL is implemented on a campus, the institution may not have a way to determine if it has been done well. So while colleges are incorporating QL or quantitative reasoning into their institutional learning outcomes, and the AAC&U provides an assessment rubric, assessment remains problematic.

Logistical Obstacles

Faculty must address problems regarding how to develop QL curricula that meet a variety of academic needs, how and where to incorporate QL into non-math disciplines, and how to find appropriate materials such as textbooks (Bennison, 2015; Blair, 2006; Steele & Kiliç-Bahi, 2008; Van Peursem et al., 2012). These issues are exacerbated by the diversity of students' mathematical backgrounds (Barker et al., 2004). Curricula are intertwined with pedagogy (Hughes-Halett, 2001), and QL requires novel approaches to teaching. Knowing how and when to use technology, maintaining consistency throughout campus departments, and the tendency of students and faculty alike to treat disciplines as distinct and discrete are also obstacles to interdisciplinary QL (Barker et al., 2004; Hughes-Halett, 2001; Madison & Steen, 2009).

Adding to the logistical obstacles, there is disagreement over who should lead such change. Some question whether or not math teachers should lead interdisciplinary QL efforts, since training for mathematics educators does not include QL (Madison, 2012); many math teachers believe that the reason for students to learn math is to prepare them for calculus, and that QL is a watering-down of the math curriculum (D. Cohen, 1995; Gordon, 2006). On the other hand, because college faculty have been trained in their own disciplines, some may themselves be quantitatively illiterate (Burn, 2006; Madison & Steen, 2009), pointing to the need for professional development.

Parallels to Writing Across the Curriculum

Some of the above obstacles were identified by Hillyard (2012), who drew comparisons between the interdisciplinary QL movement and writing across the curriculum (WAC). She noted the similarity in the inception and trajectory of the two movements, with WAC preceding QL by about 15 years. WAC obstacles that parallel those of QL are institutional buy-in and the difficulty in assessing an across-the-curriculum literacy. Another parallel exists regarding responsibility. Non-English faculty viewed teaching writing as the job of the English department, while English department faculty were reluctant to teach skills beyond mechanics and literacy. Many may assume that literacy skills should be taught in an established department (English, in the case of WAC), which causes funding issues. It can be difficult to obtain outside funding for a literacy the instruction of which is assumed to have already been institutionalized. Hillyard recommended that those in pursuit of QL across the curriculum adopt four WAC strategies: (a) a pedagogical shift, (b) developing faculty and student support resources, such as a student center, (c) development of professional networks, and (d) thoughtfully contextualizing the literacy. Though the road map is there, much work remains. For an across-the-curriculum movement, the work must be shared by faculty and administrators. The next section provides a theoretical framework for bringing together faculty and administrators.

Theoretical Framework

The approach to QL used by MAC^3 participants was grassroots in nature. Faculty members attended professional development workshops to develop curricula that they planned to use on their campuses. As the findings of this study reveal, their ability to do so depended largely on decisions made by administrators. With this being the case, this study is framed by a theory of convergence developed by Kezar, who authored or partnered to produce several relevant pieces of work (Kezar, 2012; Kezar & Eckel, 2002a; Kezar & Lester, 2011). The theory considers how efforts of grassroots leaders converge with administrative authority to expand and solidify their effectiveness. Bottom-up convergence theory is evidence-based, as (Kezar, 2012) described its workings through a multicase study of grassroots college leaders that focused on senesemaking/sensegiving to effect change at their institutions, their goals being to incorporate interdisciplinary approaches to curricula. Much of the literature about QL across the curriculum in particular involves transforming views held by faculty and administrators. Kezar and Eckel (2002a) demonstrated how sensemaking and sensegiving can be realized in top-down efforts, and Kezar (2013) applied this same lens to bottom-up changes. Convergence is required for real change to occur, whether initiating from the top or at the grassroots level. Before describing Kezar and colleagues' work in great detail, it is helpful to better understand postsecondary institutions as loosely coupled systems.

Weick's Loosely Coupled Systems

The need for convergence and faculty transformation lies partially in the disconnected nature of higher education described by Weick (1976). Weick described educational institutions as loosely coupled systems. By this he meant that the various departments and constituents of a school campus can act independently of each other; one unit can make changes while other units remain unaffected. Amey, Jessup-Anger, and Jessup-Anger (2008) articulated what this looks like in the case of community colleges: disciplines, departments, and technical education are situated within a credit and non-credit curriculum that may make up a single-campus or multicampus community college district. The system has many parts, or silos, that make interdisciplinary change difficult to implement.

A systemwide change, such as implementing across-the-curriculum QL, would require approval from various constituent groups. Decision making on a community college campus is often done through shared governance. The shared governance structure of community colleges involves students, full- and part-time faculty, the academic senate, and faculty unions, all of whom work with administrators (chairs and deans at the department or division level, and vice presidents and presidents at higher levels) and elected trustees (Amey et al., 2008). Major changes are brought before the various constituent groups—faculty, administration, and students—through committees, the union, and the academic senate for approval. California's AB 1727 gave the academic senate responsibility for academic and professional matters (Collins, 2002). The senate is the body through which faculty are represented to the administration and the board (Howell, 1997). In sum, campuswide decisions are jointly made.

Convergence

Convergence is needed because systemwide changes are difficult when the system is loosely coupled. This means that across-the-curriculum initiatives can be difficult to implement. In order for such efforts effectively to take root, campus leaders must bridge the gaps across the system. Sometimes, administrators must depend on faculty to enact their visions; other times, change starts with a core group of faculty who then "manage up" (Kezar & Lester, 2011, p. 231) and gain the support of administrators to institutionalize change. This bridging of gaps between management and faculty is a type of convergence (Kezar, 2012).

Convergence occurs when top-down leaders with authority join with bottom-up leaders who do not have authority to implement or institutionalize change efforts. Multidisciplinary QL initiatives can originate at either the administrative or grassroots level. Because of the grassroots nature of the work done by participants in this study, bottom-up convergence provided the theoretical framework. Bottom-up convergence occurs when grassroots proponents reach out to those in positions of authority to legitimize or diffuse an innovation (Kezar, 2012; Kezar & Lester, 2011). In the case of a community college campus, bottom-up convergence can occur when individual and small groups of faculty initiate change, form a broad base of institutional buy-in, and eventually win the support of administrators (Kezar & Lester, 2011). Often, one step in legitimizing grassroots efforts is securing outside grant funding. One sign that the effort is institutionalized is that the institution incorporates the change into its operational budget.

Kezar and Lester (2011) presented bottom-up convergence, an evidence-based theory, as a unique contribution to leadership theory that resulted from studying grassroots leaders at multiple higher education institutions. Their 2011 study was situated in 4-year colleges and universities and articulated strategies used and obstacles faced by grassroots leaders when working toward convergence. Successful convergence required negotiating skills, managing up—providing specific support and information to those with authority—and careful timing. Administrative buy-in without a firm grassroots base was viewed with skepticism; delaying convergence for too long subjected grassroots leaders to fatigue (Kezar & Lester, 2011). In addition to fatigue, bottom-up leaders faced obstacles that included limited resources, turnover in personnel, and diverse faculty viewpoints.

Sensemaking and Sensegiving

Kezar and Eckel (2002a) and Kezar (2013) provided further grounding for convergence theory in their presentations of sensemaking and sensegiving. Sensemaking and sensegiving refer to processes that affect institutional understanding. Sensemaking refers to change leaders developing an understanding of an intended institutional change, while sensegiving refers to transmitting that understanding to others with the intent of influencing outcomes and building support (Kezar, 2013). Two studies have demonstrated how sensemaking and sensegiving result in convergence on college campuses. Building on Gioia and Chittipeddi's (1991) work on sensemaking, Kezar and Eckel's (2002a) multiple case studies included a community college's top-down transformation from a teaching-centered institution to a learning-centered institution. Kezar's (2013) study of 28 4-year colleges and universities filled a gap in the literature on sensemaking and sensegiving in that it was the first to explore bottom-up convergence. Community colleges were not addressed directly in the latter study, though it is reasonable to expect that some principles would apply to such a setting.

Elements that led to the community college's successful transformation in Kezar and Eckel's (2002a) study included a state-imposed criterion for measuring student success, strong administrative support, and communication. Sensemaking was achieved through the formation of a leadership team, and sensegiving[4] occurred in roundtable conversations that occurred over a period of time. Participants were subsequently invited to multiple workshops, through which they gained a shared understanding about the transformation. Staff development was key for sensemaking and sensegiving. Having developed a large support base and a shared understanding of the institutional change, the college reached its transformational goal. It was noted that senior administrators played a larger role in this process in community colleges than in universities (Kezar & Eckel, 2002a).

The goals for the 28 institutions in Kezar's (2013) study centered around interdisciplinary work. The study lasted for three years, by the end of which some institutions had made more progress toward institutionalization than others. Strategies used by the most successful efforts included campuswide dialogues, connecting initiatives to educational goals, and the use of pilot courses developed by groups of faculty. The pilot courses allowed bottom-up leaders early opportunities for individual sensemaking, while the dialogues allowed for institutional sensemaking. Sensegiving was achieved in part when faculty presented findings demonstrating student outcomes. Successful teams found themselves repeating their messages because of administrative personnel changes. Learning communities of campus personnel were instrumental

[4] The authors did not explicitly call it sensegiving, though the activities described fit the definition in Kezar's (2013) later study.

in seeing their work through to implementation. Grassroots leaders who lacked formal power found that persuasion was a key strategy in both building a faculty base and garnering administrative support. Those leading the change initiatives had to persuade their colleagues that interdisciplinarity was effective in achieving student learning outcomes and their administrators that they needed to make changes at the campus level to remove obstacles to implementation. The initiative leaders had to work through challenges that included diverse faculty perspectives, unsupportive departments, and lack of understanding of interdisciplinary work. The most common reason that efforts stalled prior to institutionalization was that sensemaking and sensegiving processes did not continue after the initial stages of mobilization (Kezar, 2013).

The literature describes the MAC3 directors' sensemaking and sensegiving process on their own campus (Hillyard, 2010; Leoni & Hartzler, 2010). Bottom-up convergence informed my protocols because of the grassroots nature of participants' projects. The framework involving sensemaking and sensgiving, as well as convergence, is an appropriate lens through which to view the experience of the directors and the participants of MAC^3, because of the interdisciplinary nature of the work that is the focus of this study.

Conclusion

Members of today's society need QL skills in order to flourish. Quantitative content pervades many facets of adult life, both in and out of the workplace. The gap between the ability of college graduates and the needs of employers speaks to the importance of higher education institutions rethinking how they teach QL. If graduates are to develop the habit of mind described in the literature, QL needs to be contextualized and embedded in multiple academic disciplines. Given the unique role of community colleges in the educational landscape—for some they bridge the gap between K–12 and universities; for others, they fulfill individual educational needs unrelated to transfer—it is appropriate that these campuses, in particular, embed QL across the curriculum. Such changes can be difficult to institutionalize without broad campus buy-in and involvement. Understanding how others have implemented QL across the community college curriculum will help personnel who wish to do so on other campuses.

Chapter Three:

Research Design

Quantitative literacy is an important part of life. According to employers and by international standards, American college graduates' QL skills need to improve. Prescriptive literature indicates that QL should be embedded across the college curriculum because of the wide range of contexts in which people encounter quantitative data in their everyday lives and on the job. With all of this in mind, this case study examined the process of embedding QL across the community college curriculum.

The process under consideration was promoted by MAC^3, a program that began on a single campus and grew to become a national professional development network. One goal of the study was to identify the obstacles faced by and opportunities afforded by participants in this professional development program. The bigger purpose was to increase across-the-curriculum QL efforts and ultimately increase the quantitative literacy of American college graduates. The study was guided by the following research questions:

1. To what extent were faculty able to implement interdisciplinary QL on their community college campuses?
    a. What factors supported implementation?
    b. What factors limited implementation?
2. What were the successes of and obstacles faced by the MAC^3 program?

Research Design and Rationale

To answer the research questions, I conducted a qualitative case study that examined the process of implementing interdisciplinary QL curricula. The case study included directors and participants of MAC^3 as well as additional community college faculty members who were including QL in their classes. The participants were located on 10 community college campuses.

I sought to understand what motivated project and curriculum developers, their paths to implementation (bottom-up or top-down convergence), the obstacles they faced, and (where appropriate) the strategies they used to implement multidisciplinary QL. In short, I wanted to learn about peoples' experiences with implementing change around QL and to provide a "richly descriptive" (Merriam & Tisdell, 2016, p. 37) account of participants' experiences.

A case study design was appropriate because I sought to answer "how" and "why" questions regarding a contemporary process in which I, as the researcher, had no control over the participants' behavior (Yin, 2014). Merriam and Tisdell (2016) indicated that a case study design is appropriate for a bounded system; for my study, the systems were the MAC^3 program and individual community college campuses. I was looking for similarities and points of contrast among the experiences of those involved in implementing multidisciplinary QL. A qualitative approach was appropriate because exploratory research is needed; the approach helped to give an understanding of underlying reasons, opinions, beliefs, and motivations around implementing QL. Surveys might have helped to identify campuses with the qualities I was seeking, but those data would have been more demographic in nature and would not have answered the research questions or have adequately captured the phenomenon I wished to study.

Strategies of Inquiry

Sample

My sample comprises developers and participants of the MAC^3 professional development program as well as four additional community college faculty members who were doing QL work. The MAC^3 participants and directors were all community college faculty when MAC^3 was active (2005–2010), and they were involved with interdisciplinary math curriculum development and enactment on their community college campuses. All but two were still community college faculty at the time of the study; one developer had moved to a university, and one participant became an administrator but planned to return to the classroom in the near future.

To identify potential participants, I mined the MAC^3 website and was able to find contact information for 179 participants, although some of this information was outdated. I sent emails to all of these individuals requesting information about the current status of their MAC^3 projects. I received replies from 21 MAC^3 participants. Most of their stories were similar: They were able to enact their interdisciplinary curriculum for a time but were not able to sustain it. The exception was Edmonds Community College (EdCC), the campus at which the two developers of MAC^3 worked. That campus had the widest across-the-curriculum effort I encountered.

Eleven of the 21 MAC^3 participants who responded to my inquiry agreed to participate in the study. These 11 taught at 10 different community colleges, including two at EdCC. Starting with one of the EdCC participants and using a snowballing strategy, I found four other participants at EdCC who had incorporated QL content into their courses but had not formally been part of the MAC^3 program, for a total of 15 faculty participants. The two developers of MAC^3 also agreed to participate in the study, for a total of 17 interview participants. The participants had between 13 and 30 years of experience teaching in community colleges. The disciplines of the 11 MAC^3 participants were math (n = 5), English (n = 2), the social sciences (n = 2), humanities (n = 1), and education (n = 1). Of the four remaining EdCC faculty, three were in STEM disciplines, and one taught English. This information is summarized in Table 3, including identifiers—Linda and Carrie[5], the MAC^3 developers; M1, M2, etc. for MAC^3 participants; and N1, N2, etc. for EdCC participants that did not attend MAC^3.

Table 3

Study Participants' Roles and Disciplines

Participant	Role	Discipline
Linda	MAC^3 Director	STEM
Carrie	MAC^3 Director	STEM
M1	EdCC Faculty, MAC^3 Participant	Social Sciences
M2	EdCC Faculty, MAC^3 Participant	Social Sciences
M3	MAC^3 Participant	Education
M4	MAC^3 Participant	Humanities
M5	MAC^3 Participant	English
M6	MAC^3 Participant	Math
M7	MAC^3 Participant	Math
M8	MAC^3 Participant	Math
M9	MAC^3 Participant	English
M10	MAC^3 Participant	Math
M11	MAC^3 Participant	Math
N1	EdCC Faculty	STEM
N2	EdCC Faculty	STEM
N3	EdCC Faculty	STEM
N4	EdCC Faculty	English

Sites

The sites were community colleges at which faculty participants of MAC^3 enacted their curricula. EdCC—where six faculty participants and the two directors worked—is a medium-sized community college campus in the Pacific Northwest. It is a quarter-system college with a student population of approximately 11,100 students per quarter. At the time of data collection, the average student age was 29; 40% of students were students of color, and 53% were female. Twenty-eight percent of students were receiving need-based financial aid.

[5] These names are pseudonyms.

EdCC employs 499 instructors, of whom 27.5% are full time. Full- and part-time faculty are represented by a union. The college is accredited by the Northwest Commission on Colleges and Universities, and its 27 programs of study support 63 certificates and 61 associate degrees. The programs with the highest enrollment are AA/AS degrees, pre-nursing, paralegal, business/accounting, construction management, and computer information systems.

Four of the other campuses represented in the study are also in the Pacific Northwest, two are in the Rocky Mountain region, and three are in the eastern United States. These institutions range in size from 2,000—92,000 students and 42—2630 faculty. Three are primarily rural, while six are primarily urban. Table 4 shows some key characteristics of the sites. I include additional details about some participants' colleges when discussing the findings in Chapter 4.

Table 4

Key Characteristics of Participants' Colleges

Site	**Location**	**Students**	**Faculty**	**Primarily Rural/Urban**	**Majority ethnic group(s)**
1	Pacific Northwest	7,500	345	Urban	White (70%)
2	Pacific Northwest	8,000-10,500	305	Rural	Hispanic (55%)
3	Pacific Northwest	74,000	1951	Urban	White (68%)
4	Pacific Northwest	17,000	389	Urban	White (24%) Asian/Pacific Islander (20%) African American (18%)
5	Rocky Mountain region	8,000	354	Rural	White (60%)
6	Rocky Mountain region	2,000	42	Rural	White (71%)
7	Eastern United States	12,000	538	Urban	White (63%)
8	Eastern United States	25,000	1294	Urban	White (68%)
9	Eastern United States	92,000	2630	Urban	Hispanic (71%)

Quantitative Literacy at the Research Sites

In all, there were 10 physical sites included in the study, and the degree to which QL was embedded across their curricula varied. The literature indicates several criteria that can be used to measure the extent to which QL is embedded across a community college curriculum:

- the college has quantitative components in courses other than math (Blair, 2006; Richardson & McCallum, 2003; Steen, 2001a);
- there is cooperation across multiple departments (Korey & Hillyard, 2010);
- the campus has an Institutional Learning Outcome for Quantitative Literacy or Quantitative Reasoning (Steele & Kiliç-Bahi, 2008);
- there are learning communities for students that incorporate quantitative content (Hartzler & Leoni, 2006); and
- the campus has a Quantitative Literacy Center (Bookman et al., 2008).

EdCC satisfies the first of these three criteria, and it used to have learning communities—two or more classes into which a cohort of students take together; meetings for the classes can be held simultaneously or at different times. Thus, based on the above criteria, EdCC's curriculum includes interdisciplinary QL. Some of the other institutions in the study satisfied the first of the five criteria listed above and also used to have learning communities and cooperation across departments but did not have true across-the-curriculum QL efforts. Participants from these schools had nevertheless been involved with MAC[3] and were included in order to learn about the obstacles they encountered.

Data Collection Methods

Interviews. I conducted interviews in August through October 2017 with 17 individuals who had been involved in implementing interdisciplinary QL on their campuses. My contact with the participants was initiated via email, and the interviews were conducted using online meeting platforms and by telephone. Prior to participating in the study, participants were provided with a Study Information Sheet that outlined the purpose of the study as well as the participant's rights (see Appendix A).

The interviews lasted from 26 to 69 minutes and were digitally recorded and then transcribed. (I conducted a follow-up interview with one participant whose original interview was 26 minutes, and whose follow-up was 15 minutes, for a combined total of 41 minutes.) The average interview length was 47 minutes. In these conversations, I sought to learn about participants' motivations and experiences in their interdisciplinary efforts. (Appendix B contains the interview protocols.)

Websites and documents. One of the MAC^3 directors provided evaluations of the program and its predecessor, Mathematics Across the Curriculum (MAC), that were conducted by an external evaluator. The reports identified individual participants in the projects, the institutions with which they were affiliated, and major project accomplishments. The MAC report covered the period from April 2001 through March 2005; it was the final report for the project (Hartzler, 2005). The MAC^3 annual evaluation report covered May 2009 through April 2010 (Gilliland, 2010). I also received an evaluation report for MAC^3 that presented student survey results for 2005 through 2008 (Korey, 2008).

I examined the MAC^3 website as well as institutional websites for information regarding QL on each campus and to identify campus characteristics; a selection of the findings from these examinations is presented in Chapter 4. I also asked participants to provide me with any QL-related course materials or syllabi to further my understanding of what their quantitative curricula entailed.

Data Analysis

My approach to coding the interview and is what Saldaña (2009) called “eclectic coding,” (p. 51) because I used multiple coding approaches. During the first coding cycle, I used *attribute coding* to identify characteristics of each participant, such as years of teaching experience. To organize the data, I used *structural coding*—identifying phrases in interview data that are content-based and relate to research questions—and *descriptive coding* to develop basic categories. The results of the first coding cycle were themes (or categories) within the data. Then to develop a conceptual understanding of the data, I conducted a second coding cycle consisting of pattern coding and focused coding. Through *pattern coding*, I identified major themes that emerged from the data, collapsing some of the categories from the first coding cycle. I then used *focused coding* to further refine the categories, combining and splitting the data into subcategories. Attribute coding and structural coding were also used for document and website analysis (Saldaña, 2009).

Interview transcript analysis. After each interview was completed, I had the recordings transcribed and then analyzed the transcripts according to themes found in the literature about successes and challenges related to interdisciplinary efforts and to QL in particular.

When I analyzed the first few transcripts, I coded using broad categories that roughly corresponded to positive and negative comments. After reading four or five of the transcripts, I began to observe more specific categories within the data. I then went back over the first transcripts and coded according to the following 12 categories: collaboration, obstacles, overcoming obstacles, QL instruction/classroom/projects, motivation, benefits/outcomes to students, benefits/outcomes to faculty, instructor perceptions (essentially a catch-all category), administrative support, MAC^3 format, connection to MAC^3, and plans to continue (for the MAC^3 directors).

I separated the transcripts into three groups: MAC^3 directors, MAC^3 participants across all 10 campuses, and EdCC faculty—both MAC^3 participants and non-participants. (Note that some participants fell into both of latter two groups.) I then combined all of the data for a particular category into a single document but retained the groups of transcripts. That is, I created a document for *collaboration* that included data from MAC^3 participants. I had a second *collaboration* document for EdCC faculty. Prior to generating what ultimately became my findings, I reviewed each coded piece of data to ensure that I had coded it correctly. Finally, I reviewed all of the transcript text I had not coded to ensure that I had not missed anything of value to the study. I analyzed each of the categorical documents for subthemes. The findings in the next chapter are the result of this iterative analysis process.

Website and document analysis. I reviewed the external evaluation documents in order to triangulate statements by interview participants. I also examined MAC^3 project descriptions on the AMATYC MAC^3 website to further understand the QL content described by the interview participants. In order to characterize the extent to which study participants implemented QL in their classes, I compared descriptions, verbal and in print, against a QL rubric created by the AAC&U. The AAC&U (2009) VALUE Rubric for Quantitative Literacy includes a definition (see Chapter 2) and various components of QL, as well as criteria for assessing student work. The components therein are given in Chapter 3. Table 5 connects data collection methods to the research questions.

Table 5

Research Questions and Data Sources

Research Questions	Data Sources
1. To what extent were faculty able to implement interdisciplinary QL on their community college campuses? a. What factors supported implementation? b. What factors limited implementation?	Coded interviews with MAC^3 participants Coded interviews with EdCC faculty members Document and website analysis
2. What were the successes of and obstacles faced by the MAC^3 program?	Coded interviews with MAC^3 developers Coded interviews with MAC^3 participants Document and website analysis External evaluation materials

Ethical Issues

I asked faculty about barriers to curricular implementation on their campuses. In some cases, they pointed to administrators. I have done my best to protect participants' identities to reduce the possibility of backlash, even though participants were, in some cases, tenured faculty. In my discussion of the findings, I use codes to represent MAC^3 participants and EdCC faculty, and, with the exception of EdCC, I do not indicate participants' individual colleges. I have sought to provide information to individuals who want to do things similar to what my participants did. Thus, I needed to present a factual record. Even though writings describing MAC^3 have already been published, I used pseudonyms for the two directors in hopes of providing confidentiality related to which particular comments were made by which director.

I came to this study with some biases. I have taught math on community college campuses for 14 years. During this time, I have taught the full range of community college math courses, from prealgebra through calculus and differential equations. Over the course of my career in teaching mathematics, I have become disillusioned with the approaches taken to teaching math to non-STEM majors. I believe that math educators have done the discipline and a great many students a disservice by subjecting non-STEM majors to rigorous abstract mathematics while ignoring the practical side of math in the form of QL. The issue is particularly pointed considering how many students are deterred from higher education because of math requirements (e.g. Bailey, Jeong, & Cho, 2010). I believe that teaching math content with relevance to the real world and everyday life is a much better course of action. Thus, I had to be careful not to dismiss what I might have considered to be math as an academic exercise—properly cultivated, the skills contained in these lessons have great potential as transferrable skills.

Another bias relates to the structure of community colleges. Faculty are fairly autonomous but, without administrative support, reaching across disciplinary aisles is often not rewarded. Both the literature and my personal experience suggest that if efforts are not incentivized and supported, the best of intentions will yield no fruit. I expected to hear that administrations are a hindrance. That said, I also looked for ways in which administrators have been supportive of interdisciplinary efforts. I was mindful not to exaggerate the effects of administrators in either direction.

Finally, I was careful to maintain confidentiality. To this end, data are protected on my password-protected computer and an encrypted cloud service (Box, through my UCLA email account). I have kept hard copies of documents in a secure location to which only I have access.

Credibility and Trustworthiness

I anticipated possible threats to credibility. One was that of reactivity. I asked directors and participants about a program with a goal that likely aligned with their own priorities. As such, I tried to be alert for social desirability or overstatements of success or scale. To mitigate this risk, I triangulated data using document analysis where possible. Further, I was aware that participants might have had mixed feelings about not having sustained QL at their colleges. It was my hope to build rapport and to ask probing questions, increasing the dependability of the interview data.

Another possible credibility threat relates to transferability—how applicable my findings are outside of this group of participants. With an eye toward how someone would develop a similar national network or initiate interdisciplinary projects with math content on other campuses, I have provided rich descriptions of my findings.

Summary

The embedded case study design of this research involved the developers of the MAC^3 professional development network, MAC^3 participants at various community colleges, and other faculty members at EdCC. Interviews with these participants, as well as document and website analysis, provided information about the process of implementing QL across the community college curriculum and the barriers encountered in the process.

Chapter Four:

Findings

Through a historical case study, I discovered that most MAC^3 projects were implemented at least once, but few saw long-term implementation; in general, they did not lead to campuswide initiatives. Lack of administrative and financial support tended to limit the extent to which MAC^3 projects were used. In this chapter, I describe the program and its development, the experiences of four MAC^3 participants, the successes of and obstacles faced by those implementing the MAC^3 program, and the ways in which some participants are continuing to address QL.

MAC^3 Background and Goals

When MAC^3 was created, its directors, Linda and Carrie were faculty members at EdCC; at the time of my interviews, they each had between 20 and 30 years of experience teaching STEM disciplines on community college campuses. They did not set out to build a national professional development network. Rather, their work started as an effort to address an institutional learning outcome involving quantitative reasoning. They brought speakers who were at the forefront of the then new QL movement and worked with their colleagues to build QL into various disciplines on their campus.

The motivation these two women had was clear. Linda described QL as “a preparation for being a productive and critical thinking citizen.” Carrie told me, “I was thinking if I can decrease that question about ‘When will I ever need this?’ and it helps students see the need and even the beauty of mathematics, the usefulness of mathematics, that that would be well worth it.” The result of their work on their campus was an NSF-funded grant project, Mathematics Across the Curriculum (MAC), the aim of which was to improve QL among community college students. The scope of MAC was their home state of Washington. For the four years during which MAC was active, Carrie says that the project "continued to get interest from faculty from around the entire state, and then the last couple years we got interest from even other schools from across the country…[that] were sending teams of faculty to our summer institutes." Linda felt that they had developed a good theory of change that was enacted by "having teams of faculty propose a curriculum treatment of some sort…that they would integrate into their course to improve the quantitative reasoning and quantitative literacy of their students within their discipline."

After gaining experience first on their campus and then on a statewide scale, Linda and Carrie wrote a grant to create MAC^3, the focus of this case study. In order to secure the $700,000 grant, which would include national dissemination, Linda and Carrie needed to secure the support of a national network—in their case, AMATYC. They had a connection to AMATYC through a regional representative, and they requested a letter of support. AMATYC agreed but wanted to be involved and ultimately became the funded agency. Linda and Carrie partnered with AMATYC, using the organization's network and conferences to increase the visibility of their project. The MAC^3 grant was active from 2005 until it expired in 2010. By this time, Linda and Carrie had worked on the project for approximately 10 years, and they felt it was time to continue with their careers as educators.

AMATYC supported Linda and Carrie by letting them present at conferences and by including information about MAC^3 in their newsletters. While MAC^3 was active, AMATYC had two professional development workshop formats, traveling workshops, and summer and winter institutes. The traveling workshops were one-day or half-day events in various locations around the country, while the institutes were retreat-style and lasted four days. Community college faculty were invited to attend these sessions. In some cases, faculty who had attended an AMATYC conference at which Linda and Carrie presented their work would go back to their institutions and put together a team that would attend a summer institute. AMATYC also included information about MAC^3 in their emails, so in other cases, faculty saw information in that format and took advantage of the professional development opportunity. On this note, Carrie said, “We reached a lot of people that way that otherwise we would not have been able—they wouldn’t have known who we were.” Of the traveling workshops, Linda said, “It was usually one day and usually attached to the AMATYC—like, it’d be the day before the AMATYC workshop or the little AMATYC—regional AMATYC conference.” In all, Linda and Carrie, with help from support personnel, delivered and/or coordinated 13 traveling workshops in various locations across the country during the life of the grant. They also planned and hosted three summer institutes in the Pacific Northwest and two winter institutes in the southeastern United States during the life of the grant.

The MAC^3 grant provided financial support for participants by paying for their lodging during the summer and winter institutes. In addition, participants received a stipend of $60 per day to help offset travel expenses. Due to cancellations and no-shows during the first year of the MAC^3 grant, participants were later required to pay a $100 deposit. This served to ensure that registrants would follow through and attend the workshop for which they signed up.

The summer and winter institutes opened with informative sessions about QL and various projects previous participants had implemented, but then participants were given time and space to work with their teams over the course of the multiday sessions. Optional workshops focused on assessing quantitative literacy and dos and don’ts of implementation, for instance. (Linda and Carrie learned early on that allowing faculty to work in their teams was more effective than requiring them to attend workshops, which is why they were optional.) At the end of the multiday MAC^3 sessions, faculty participants were expected to present the project or curriculum they had developed, and this expectation motivated them over the course of the session. Carrie said that participants "actually did come away with a lot done.…They were working conferences. That everybody was expected to, by the last day, have at least a good start on a lot of their product, and they even had to share it."

As noted above, Linda and Carrie used part of the grant to provide stipends to attendees of the summer and winter institutes. The $60-per-day stipend worked as an incentive for participants to finalize their projects, as it was paid after they submitted them either to Linda and Carrie or to a website hosted by AMATYC. Carrie called it "a little carrot we had to make sure we got copies of their materials that they created. For some, it helped offset the cost if they had to actually pay for their own travel to the site." Linda further explained why they requested participants share materials:

> You go to a conference, you get good ideas and it's really hard to implement them. What we wanted to do was to give them the time to finish and then they would have this for the beginning of the term and they knew when it was going to be taught, they had everything written out, put it on their learning management system.…It's in the syllabus, it's done.

It is clear in how Linda and Carrie spoke of their work that their aim was for teachers to put into practice new curricula. In short, their theory of change involved change.

MAC^3 participants' projects varied in scope and content. They took on various forms such as individual assignments, class projects lasting several weeks, or learning communities in which cohorts of students co-enrolled in multiple courses. Most involved a team of faculty from two disciplines, though some were single-discipline and several involved three or more disciplines. The experiences of four MAC^3 participants are presented and analyzed in the next section; here, I present a brief description of three project examples—a class assignment, a class project, and a learning community—to demonstrate how the projects varied and how math content was incorporated into non-math courses.

In the first example, a speech communications instructor worked with two math instructors to design a persuasive speech assignment where students were required to use descriptive statistics to analyze target audience demographics, reflect on why such demographics are important, and incorporate their data analysis into their speech. In another project, a math instructor and a health and human services instructor created an addiction studies project designed to provide students with tools to understand research reports and other writing containing survey and statistical data. This project was two-tiered, meaning that it spanned more than one assignment. And in yet another example, an earth sciences teacher and a math teacher created a learning community; they team-taught a project-based, one-unit course that included several projects designed to equip students with knowledge and skills to understand and analyze how various conservation measures would impact the environment and their lives. Course content included dynamics of home heating and a heat transfer model, thus contextualizing the relevant mathematics. Overall, the content of each particular project related to the disciplines of the faculty making up the team. Next, I discuss how some projects were used.

Degree of Quantitative Literacy Implementation

I consider the question of degree of implementation in two ways: the duration of QL in participants' courses and curricula, and the components of QL, as indicated by the AAC&U (2009) VALUE Rubric for Quantitative Literacy. Using the definition and description of QL in the VALUE rubric, I identified nine behaviors that indicate degree of QL implementation: (1) complete straightforward estimations and calculations; (2) complete calculations to answer meaningful questions; (3) analyze/make judgments based on quantitative information; (4) solve quantitative problems in authentic contexts and everyday life situations; (5) represent quantitative information using words, tables, graphs, and equations; (6) draw information from charts, graphs, and geometric figures; (7) communicate results for various purposes and audiences; (8) create sophisticated arguments using quantitative evidence; and (9) develop habit of mind.

Items 1–4 pertain to analysis of quantitative information and they increase in sophistication—that is, 4 is more sophisticated than 1. Items 5–8 pertain to representing and communicating quantitative content, again with 8 being more sophisticated than 5. Item 9 is the result of repeated exposure to quantitative content and analysis, as it refers to the formation of a habit. These components are presented in Table 6.

Table 6

Components of Quantitative Literacy

	Computation/Analysis
Less sophisticated	1. Complete straightforward estimations and calculations
	2. Complete calculations to answer meaningful questions
	3. Analyze/make judgments based on quantitative information
More sophisticated	4. Solve quantitative problems in authentic contexts and everyday life situations
	Representation/Presentation
Less sophisticated	5. Represent quantitative information using words, tables, graphs, and equations
	6. Draw information from charts, graphs, and geometric figures
	7. Communicate results for various purposes and audiences
More sophisticated	8. Create sophisticated arguments using quantitative evidence
	Culmination
	9. Develop habit of mind

In this study, I interviewed 11 MAC[3] participants from 10 community colleges. For purposes of discussion, I identify them with codes (“M1” through “M11”). M1 and M2 were teaching at EdCC; the remaining participants were working at different community colleges. The participants described a wide range of implementation. Six had projects that were sustained for at least five years; three used their projects for one semester to five years; two never implemented their projects. Table 7 shows the composition of the study's participants' MAC^3 teams and the duration of implementation of their projects.

Table 7

Characteristics of MAC^3 Study Participants and Their QL Projects

Participant	Academic Area	Duration of Use	Academic Areas of Team Members	Comment
M1	Social Sciences	Ongoing	Labor Studies Life Sciences --	Two separate teams and several individual projects
M2	Social Sciences	Ongoing	Math	
M3	Education	Ongoing	Physical Sciences Life Sciences	
M4	Humanities	"Many years"	Math	
M5	English	4–5 years	Math	
M6	Math	5 years 2 years	Humanities Social Sciences	Two projects with two separate partners
M7	Math	3 years	Life Sciences	
M8	Math	2–3 semesters	Physical Sciences	
M9	English	1 or 2 times	Math	
M10	Math	Not used	--	Individual project
M11	Math	Not used	English and reading/writing	Three-discipline team

To give the reader a sense of the results of MAC^3, I discuss four participants' experiences below. I address the components of QL in participants' curricula both within these stories and later in this chapter.

Stories of Four MAC^3 Participants

First, I describe an instructor who still uses what he learned at MAC^3 over 10 years after attending summer institutes. Second, I describe a learning community—active for four or five years—in which students were co-enrolled in math and English courses. Third, I discuss another learning community that existed for three years. Finally, I present a planned project that was never actually implemented due to lack of support at the participant's college. The first two stories are examples of the long-term impacts MAC^3 has had on some of its participants. The third and fourth highlight some of the difficulties in diffusing innovation.

QL in social science. M1 has taught a discipline in the social sciences for 19 years at EdCC. He first attended MAC, the precursor of MAC^3. He was invited to participate by the directors of MAC^3 and said he sees math as a natural part of his discipline. His experiences with MAC and MAC^3 showed him the value of interdisciplinary collaboration. In addition to learning various ways to incorporate QL into his social science courses, the professional development provided by MAC^3 gave him the tools to develop an interdisciplinary service learning program on his campus. Below I describe how he included QL into his classes after his MAC^3 experience; his interdisciplinary service learning program is described later in the chapter.

The MAC^3 website contains various projects developed by M1 with different interdisciplinary partners. In one team, M1 paired his social science discipline with labor studies to create a service learning project. In another, he paired with a life sciences faculty member to create a two-course learning community. He also worked alone to create several service learning projects within his discipline. The interdisciplinary pairings have not continued, but he does continue to incorporate QL into his own courses.

In his ongoing work, he has incorporated several components from the AAC&U (2009) VALUE rubric. His students have completed straightforward estimations and calculations; completed calculations to answer meaningful questions; made judgments based on quantitative information; represented information using words, tables, graphs, and equations; and drawn information from charts, graphs, and geometric figures. In particular, they have measured physical objects, such as stride lengths of hominids and forelimbs and hindlimbs of humans and other primates. His students have also worked with very small amounts of liquids, using micropipettes, requiring them to convert between liters and microliters and to understand the differences in scale between these units of measure. His students have also examined data from surveys, charts, and graphs to identify patterns in human behavior. In some of his classes, students have used large data sets to analyze wildlife behavior. In this case, data collection was automated using remote cameras and computer software, and the data were used to monitor wildlife and shared with local tribes and municipal governments. In his words, his students were able to see "modern applications of quantitative analysis in addressing conservation issues related to fish and wildlife."

Not all of M1's students worked with all of the data, and the data were generally analyzed by M1 himself, though he modeled the process. Students focused more on interpreting results than performing the analysis. When I asked how the math his students encountered differed from what they might have seen in traditional math classes, M1 said,

> it's a little more practical probably than a lot of what they're experiencing.…It's a lot of measurement, interpreting and manipulating data, generating charts and graphs. It doesn't require a lot of algebra.…There's a lot of interpretive—quantitative literacy skills rather than statistical analysis.

M1's understanding of QL is embodied in his students' use of real-world data and in how they interpreted those data.

M1's experience is rare in that he has been able to continue to incorporate QL into his classes for over 10 years. One motivating factor for M1 was a desire to make math valuable and relevant to students. He also identified ways in which the administration has been supportive of interdisciplinary QL efforts on his campus. In general, he said, they have been supportive of innovation—a statement echoed by his coworker, M2. I asked M1 why he has been able to collaborate with his colleagues as much as he has. He pointed to the MAC and MAC^3 programs as models for his service learning work, which is collaborative in nature. M2 described his campus culture as having been supportive of team teaching when MAC and MAC^3 were active but added that it was expensive. In the case of these two MAC^3 participants, their administration had fostered a culture that valued and supported learning communities in particular and collaboration in general.

An English–math learning community. M5 had taught English for 19 years on her campus in the Pacific Northwest at the time of her interview with me. She paired with a math instructor to develop a learning community on their campus. Her community college, according to the website, enrolls about 8,000–10,500 students per year, 55% of whom are Hispanic/Latino and 35% of whom are White. The course completion rate of the college is about 82%, and the graduation rate is around 30%. The college's accreditation self-study indicated that, in the 2009–2010 academic year, the mostly rural students were supported by 118 full-time faculty members and 187 part-time faculty members. M5 said that faculty on her campus were encouraged by the administration to participate in summer workshops about learning communities. The campus MAC^3 team, of which M5 was a part, was able to sustain its learning community for four to five years before the college withdrew financial support.

The focus of the learning community was improving outcomes for basic skills students, and the classes into which students enrolled were the lowest levels of the respective disciplines. As M5 said, "We just found different ways that we could connect those two curriculums [of English and math]." Students did studies on campus that required the use of proportions, fractions, and decimals and that included some analysis. The students bridged the apparent content gap between the two disciplines in part by creating portfolios that included their work and a learning reflection. Additionally, the faculty team incorporated college knowledge into their classes and provided advising support to their students. M5 described the partnership as co-teaching, indicating that while students knew which teacher taught each discipline, they were able to approach either teacher for assistance when they needed it. This was possible because the instructors were both comfortable with the content in each course at this level.

While M5's MAC^3 learning community has not continued, some of her students are still exposed to QL content. When I asked if she still incorporated QL in her English course, M5 said, "not in the same way." She continued, "in the lower level, I don't bring in direct math content anymore, but it's the same vulnerable population of students." In higher-level courses, her students do see some statistics but she emphasized that QL is about a habit of mind, disposition, and problem solving. One way in which she is able to continue to incorporate QL is by having her argument-writing students consider "thorny issues" in the news, such as topics related to health care, the food industry, or law and justice. "Occasionally, we're doing real math. More frequently, we're understanding how to communicate numbers in meaningful ways visually."

Like M1, M5 was among those who said that they wanted to make math relevant for students. M5 also wanted to improve outcomes for a vulnerable population and have support for learning communities in general. Also like M1, she was among those who described ways in which the administration was supportive of the MAC^3 QL project. In addition to having some administrative support, M5 found the format of MAC^3 itself to be beneficial:

> I don't think I've been to a better setup than that, to be honest. We had so much time to collaborate with our team and then time to interact with other teams and time to have experts come in and support our work.

The MAC^3 format resonated with M5. In particular, she spoke of the power of working in groups and of having to present their work at the close of the session:

> I just so appreciated having that professional time to work with my team and to have some people come in and provide pushes of guidance here and there. It's like we got so much done. It was just like deeply invested, plenty of time. We had to be responsible at the end for presenting information and I thought it worked really, really well.

The AAC&U (2009) VALUE rubric skills evident in M5's description are completing straightforward estimations and calculations; completing calculations to answer meaningful questions; making judgments based on quantitative information; solving quantitative problems in authentic contexts; developing a habit of mind; representing quantitative information using words, tables, graphs, and equations; and communicating results for various purposes. This speaks to a high degree of QL incorporation in her English courses.

M5's experience has similarities to M1's experience. Though neither of their initial interdisciplinary projects is still in use, they have continued to find ways to include quantitative content in their non-math courses. In neither case is there sustained interdisciplinary work with other faculty members around QL, however. At the time of my interview, M5 was collaborating on a reading–writing pairing, but QL was not a focus. Her QL effort had not spread beyond her own classroom.

A math–life sciences learning community. M7 has taught math on his Pacific Northwest college campus for 17 years, 15 of which have been as a full-time faculty member. The college's website gives a student head count of about 7,000 students, of which approximately 8% are Hispanic, 3% are Asian, 3% are African American, and 5% identify as multiracial (11% did not report their race). Presumably, approximately 70% are White, as White is not listed, and the races and ethnicities given total approximately 30%. The median age of students at M7's school is 22 years, and approximately 60% of students attend the college full time. Nearly 75% of students indicated that they wished to transfer to baccalaureate-granting institutions. According to a 2014 accreditation self-study follow-up document, the college employed 172 full-time instructors and 295 part-time instructors during the 2013–2014 academic year.

M7 has taken advantage of several grant opportunities over the last several years, one of which involved MAC[3]. One thing M7 had in his favor is that his campus already had learning communities. He described them as "not uncommon," indicating that it was typical for his campus to have five or six learning communities at a time. He was able to use the learning community he developed with his colleague in the life sciences for three years, until his college refocused its learning communities in a different direction. His was the type of learning community in which students enrolled into two concurrent courses that were co-taught by the two instructors. Students conducted projects on campus or in the woods surrounding the campus. Their studies culminated in an in-class presentation and a written report that, as M7 explained, described "some sort of summary data analysis…some sort of growth modeling…some people did some stuff with regression. Some people did a lot of stuff with displays of data…at a pretty low level of mathematics and of scientific rigor."

M7's students did a range of QL tasks including completing straightforward estimations and calculations; completing calculations to answer meaningful questions; making judgments based on quantitative information; developing a habit of mind; representing quantitative information using words, tables, graphs, and equations; and communicating results for various purposes and audiences. He says he was motivated by an opportunity to provide mathematical support to his life sciences colleague who, as he explained, "wanted to do more interesting things with his students, but they didn't necessarily have the mathematical background." As M7 put it, "We thought this would be a good way that he could get more of the mathematics involved without cutting into the [life sciences] content." The time factor of which M7 spoke is a logistical obstacle that I discuss later in this chapter. In his case, the learning community allowed students to get mathematical support but not at the expense of non-math content.

M7's involvement in learning communities has continued, though his MAC^3 project has not. Since his discipline is mathematics, once the above learning community no longer existed, the interdisciplinary nature of his QL work stopped. He explained, "I'm using some of the content that I developed in other classes that I teach that are on the quantitative literacy pathway that we have." So, like M1 and M5, his experience with MAC^3 lives on in his own classroom. His current learning community, however, is focused on helping students succeed in college generally, with content that includes study skills and mathematical literacy. He cited his campus leadership's motivation as focused on success rates and retention.

When I asked him how his administration supported him, he spoke of financial support to attend MAC^3 and a stipend to develop the curriculum. He followed that with, "then how did they not support us? Well, we didn't get to continue doing it after a couple years." In this, he is similar to M8 and M9 in that school support did not continue in a way that sustained interdisciplinary QL work. As with M1 and M5, M7's QL work continued as an individual effort. This was also the case for M6, although her effort ended when she retired. This underscores a challenge for those attempting to diffuse an innovation: Individual efforts can only do so much on a community college campus. For each of the cases discussed so far, the QL effort continued due to individual efforts but did not spread across campus or across the curricula. While each case represents progress for QL instruction, the effect is small without campuswide support. The next case shows how lack of support can hamper efforts entirely.

A project never implemented. M11 has 28 years of experience teaching math at a community college in the Rocky Mountain region of the United States. The college website indicates that the school has approximately 8,000 students, 35% of whom attend full time. Fifty-eight percent of the college's students are aged 21 or under. Approximately 60% of the students are White, 33% are Hispanic/Latino, 2% are African American, and 1% are Asian. According to the school's website, of the approximately 7,100 students enrolled in the 2014–2015 school year, roughly 1,100 earned degrees and/or certificates, a rate of 15.5%. Cohorts that started in 2010, 2011, and 2012 transferred to baccalaureate-granting institutions at a rate of 19%.

M11 and two colleagues responded to an invitation to participate in a MAC^3 summer institute. She and her team created a curriculum for a learning community that would include students enrolled in English, math, and reading courses. The plan was to have students enroll in a course in each of the three disciplines as a cohort. The instructors would teach as a team, sometimes together and other times in a "take-turn" format. The team planned themes that would span the three courses, such as time management, budgeting, financial aid, and career-oriented content. Based on M11's description, the curriculum would have included completing straightforward estimations and calculations, completing calculations to answer meaningful questions, making judgments based on quantitative information, solving quantitative problems in authentic contexts, and developing a habit of mind. She says the way in which her course content would have differed from traditional mathematics in that she would have put it in context.

This project was never put into practice because the college ultimately did not incorporate learning communities into its curriculum. As M11 said, "Our college, shortly after, chose not to support learning communities in general. It just kind of faded away, and we never got to even implement it." M11 valued learning communities in general, and she was not alone in this on her campus. She described another similar experience at her school:

> There were a few faculty that had been here for a number of years at that time, really bought in and knew benefits of learning communities, held some special meetings for us

> all to talk, even invited me to go with them to an interdisciplinary learning community conference.…But I think ran into the same roadblocks, because she finally just gave up. One lady, in particular…just gave up and said, "Even our deans aren't helping. The vice president is not working for these learning communities." So we finally just quit and gave up.

M11 said that her administration could have been more effective in promoting learning communities. She also indicated, however, that she and those with whom she worked had difficulty generating faculty buy-in, the main obstacle being compensation. In discussing the extra effort required to plan and implement learning communities, her fellow faculty members "wanted to be compensated, either monetary or release time from other teaching duties, and it got to be a little bit of greed on faculty positions." As discussed later in this chapter, faculty compensation was identified by others as an obstacle to interdisciplinary work on community college campuses.

In the above four cases, participant motivation and administrative decisions influenced the participants' experiences. The ability of M1, M5, and M7, as well as the inability of M11, to teach as part of a QL-focused learning community rested on the support (or lack thereof) of their administrations. M1 taught at EdCC, where Linda and Carrie developed MAC and then MAC^3 as a response to the college's focus on a quantitative reasoning institutional learning outcome; in M5's case, the administration was promoting learning communities; on M7's campus, learning communities were a normal part of campus practice. M1 and M5 worked on campuses that eventually stopped supporting learning communities, thus effectively ending their multidisciplinary QL partnerships with their colleagues. M7's partnerships continued, but with a different focus that came from the administration. In M11's case, administrative decisions meant her planned learning community was never built.

The interdisciplinary QL work—both planned and executed—of these four participants was in keeping with their motivating factors. M1's pairings and continued QL focus revolved (and have continued to revolve) around service learning and what he described as a natural component of his discipline. M5 was interested in helping a vulnerable population succeed, and she was able to use her learning community to address student success issues in addition to promoting QL. M7's math course acted in a support role for his colleague, with an eye on student success. Their work has continued to be fueled by these motivating factors. In the contrasting case, M11's interest in learning communities was overshadowed by decisions made by others.

The Interdisciplinary Teams of MAC[3]

As described above, M1 worked with a teammate in labor studies to develop curricula. He also worked with a teammate in the life sciences. Additionally, he created curricula on his own. M5's project paired English with math; M7 paired math with life sciences; and M11's learning community would have included math, English, and reading. To help the reader visualize the interdisciplinary nature of the teams with which M1, M5, M7, and M11 worked, Table 8 is a two-way table that represents interdisciplinary pairings. In each case, the participant is identified at the intersection of the disciplines reflected in her or his team. M1 appears three times because he produced projects as part of three separate teams (though one "team" was a solo effort). The box containing M11 is in grey to indicate that it was a three-discipline team that included English, reading/writing, and mathematics.

Table 8

Composition of Teams Involving M1, M5, M7, and M11

	English	Labor Studies	Life Sciences	Life Sciences	Mathematics	Reading/Writing	Social Sciences
English							
Labor Studies							
Life Sciences							
Life Sciences							
Mathematics	M5		M7				
Reading/Writing	**M11**[a]						
Social Sciences		M1	M1				M1

[a] M11's project included three disciplines: English, reading/writing, and mathematics.

Table 9 reflects the interdisciplinary teams of all of the MAC[3] participants in this study. Rather than identifying the participants by their identifiers (e.g., M1, M3) in Table 9, I have indicated the number of teams that include each discipline grouping. That is, two participants were part of teams that involved English and math. One participant's team is not reflected in Table 9—it was a three-discipline team that included education, physical sciences, and life sciences.

Table 9

Composition of Teams Involving Study Participants

	English	Humanities	Labor Studies	Life Sciences	Mathematics	Physical Sciences	Reading/Writing	Social Sciences

English								
Humanities								
Labor Studies								
Life Sciences								
Mathematics	2	2		1	1			
Physical Sciences					1			
Reading/Writing	**1**[a]							
Social Sciences			1	1	2			1

Note. One team is not shown in the table. It included three disciplines: education, physical sciences, and life sciences.
[a] This project included three disciplines: English, reading/writing, and mathematics.

Table 10 represents the interdisciplinary nature of all of the teams that participated in MAC^3. Based on analysis of the MAC^3 website, I identified 111 teams from 36 community colleges.[6] I collapsed 63 individual disciplines into 20 meta-disciplines (e.g., chemistry and physics into physical sciences; dental, nursing, and health into health and human services). I do not provide specific disciplines in all cases for two reasons: (a) to protect the anonymity of participants and (b) for ease of representation of the interdisciplinary teams that participated in MAC^3. In some cases, MAC^3 participants gave broader discipline categories, such as natural and social sciences, which were not combined into any other meta-discipline.

As in Table 9, the numbers in the boxes of Table 10 indicate the number of teams of a particular composition, in particular the two disciplines for which the box is an intersection. For instance, there were two business–math pairings and five English–math pairings. Most of the teams represented in Table 10 were two-discipline teams. The grey boxes indicate three-

[6] My use of "team" differs from Linda's use of the word. Linda identified 59 teams that were groups of faculty from particular colleges that attended particular sessions. I use the term to indicate a group of faculty who created a project and/or curriculum. That is, a group of six faculty from one college that attended a summer institute would be counted by Linda as one team, though if they split up into pairs that created three projects, I would count them as three teams.

discipline teams that include math as well as the two intersecting disciplines. In addition to the teams in Table 10, there was one three-discipline team that did not include math (M3's team of education, life sciences, and physical sciences) and two four-discipline teams that did include math. The other three disciplines for one of these teams was business, education, and health and human services; for the other team, they were education, life sciences, and social sciences.

Table 10

Composition of MAC^3 Interdisciplinary Teams

	Business	Computer Information Systems	Computer Science	Criminal Justice	Culinary/Hospitality Management	Earth Sciences	Education	English	Health and Human Services	Humanities	Labor Studies	Languages	Life Sciences	Math	Natural and Social Sciences	Physical Sciences	Reading/Writing	Science	Social Sciences	Speech Communications
Business	3																			
Computer Information Systems		1																		
Computer Science																				
Criminal Justice																				
Culinary/Hospitality Management				**1**																
Earth Sciences						1														
Education																				
English																				
Health and Human Services								**1**												
Humanities								**1**		1										
Labor Studies											1									
Languages							**1**					1								
Life Sciences			**1**				**1**			1			1							
Math	2	2	1	2		2	2	5	3	8		3	8	11						
Natural and Social Sciences														1						
Physical Sciences										2				5		2				
Reading/Writing							**1**	**3**			1			3		2	2			
Science														3						
Social Sciences										**1**	1	1		12					1	
Speech Communications														1					**1**	

Note. Teams indicated in shaded boxes were three-discipline teams that also included math. One three-discipline team is not shown; it included education, life sciences, and physical sciences.

Quantitative Literacy Components in Participants' Projects

Based on the descriptions of their projects, M1, M5, M7, and M11 planned and/or implemented curricula that revolved mostly around the following components from the AAC&U (2009) VALUE rubric: complete straightforward computations, complete calculations to answer meaningful questions, and make judgments based on quantitative information. These elements were also the most common in the descriptions given by the rest of the interview participants. Less common were drawing information from charts and graphs and communicating results for various purposes. An element not indicated by any MAC^3 participant was creating sophisticated arguments.

These results are summarized in Table 11. Eleven participants are reflected in the table. The Total column indicates the number of participants whose projects or classwork included a particular element of QL. The *X*s for M10 and M11 are in italics because their projects were never implemented on their campuses; these marks indicate the elements their intended projects would have included. Because the projects created by M10 and M11 were not used, they are excluded from the Total column.

Table 11

Components of QL in Study Participants' Curricula

Participant	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**Total**
Duration of QL curricula usage	Ongoing	Ongoing	Ongoing	"Many years"	4–5 years	5 years, 2 years	3 years	2–3 semesters	1 or 2 times	Not used	Not used	
Complete straightforward estimations and calculations	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	*x*	*x*	9
Complete calculations to answer meaningful questions	**x**		**x**		**x**	**x**	**x**	**x**	**x**	*x*	*x*	7
Analyze/make judgments based on quantitative information	**x**	**x**	**x**		**x**	**x**	**x**	**x**			*x*	7
Solve quantitative problems in authentic contexts and everyday life situations		**x**		**x**	**x**	**x**		**x**	**x**		*x*	6
Represent quantitative information using words, tables, graphs, and equations	**x**				**x**	**x**	**x**	**x**				5
Draw information from charts, graphs, and geometric figures	**x**			**x**		**x**						3
Communicate results for various purposes and audiences			**x**		**x**	**x**	**x**					4
Create sophisticated arguments using quantitative evidence												0
Develop habit of mind		**x**			**x**	**x**	**x**		**x**	*x*	*x*	5

Note. Total column reflects number of participants whose project included that aspect of QL. "X" marks or M10 and M11 are in italics to indicate that these projects were planned but never implemented. M10 and M11 data are excluded from Total column.

Two things are evident from looking at Table 11. One is that students more often performed calculations and/or analyses than created representations of quantitative data. The other is that curricula tended to include the less sophisticated elements more often than the more sophisticated components of QL. That some components of QL were less frequently referenced could be due either to the nature of the disciplines—they may not have required argumentation in their coursework or the emphasis was on interpreting rather than presenting data—or because I did not ask directly which of the components listed in the table their students did. (I analyzed their descriptions myself to generate Table 11.) Had I directly asked what elements they included, they might have identified more or fewer elements than are shown in the table. It would also make sense that students in community college courses might not be expected to develop sophisticated arguments, as the breadth of the curriculum consists largely of introductory courses in various disciplines. Perhaps this is more commonly an expectation of students who are doing undergraduate work at universities. Whatever the case, these math and non-math faculty participants found ways to incorporate quantitative content into their curricula, in keeping with the philosophy that presenting math in authentic contexts leads to quantitative literacy.

Factors That Supported Implementation

During their interviews, the participants described various factors that supported and limited implementation of their efforts to incorporate QL in their classes. Supporting factors, which I describe in this section, include individual motivation, the MAC^3 professional development network itself, and administrative support. As I discuss in a later section, however, lack of administrative support can also act as an obstacle.

Individual motivation. Participants' motivation was instrumental because, absent a campuswide effort to incorporate QL across the curriculum, faculty members were essentially working at a grassroots level. As presented below, administrative support was somewhat hit or miss, so faculty needed to be self-motivated. A key motivating factor for MAC^3 participants was that they wanted to make math relevant. Seven said they were interested in interdisciplinary work or learning communities generally. Four of these had projects that were aimed at vulnerable populations—particularly students enrolled in basic skills. For example:

> It wasn't necessarily that math and English are natural fits; it was more that this is a population of students that isn't being successful. How can we try to work with this population because the two classes they have to take are math and English? (M5)

As M5's story earlier in this chapter indicates, administrative support was present, but she was also committed to the cause. Three other MAC^3 participants pointed to struggling students and improving retention as their reasons for attending MAC^3.

Other factors motivating the participants included that they wanted to make math relevant and that they had a holistic view of education. As M3 noted, "[QL] should be part of a literate citizen's arsenal. And yes, you can have word problems and relevant problems in math classes, but I think it works a lot better in context." This quote characterizes the views of eight MAC^3 participants who saw beyond the confines of their disciplines and considered the whole student in their approach to education.

Motivation was not always sufficient. M10, who appreciated the opportunity to connect math with other disciplines, spoke of a different motivating factor than the other participants. She was an adjunct faculty member and had hoped that by attending MAC^3 and creating a course for her department, she would be hired as a full-time instructor. In her words, "what motivated me was…I wanted to get a full-time job." The class she created at MAC^3 was not adopted by her college, though she said that she continued to find ways to connect math with students' lives.

The MAC^3 format. Working under the MAC^3 grant, Linda and Carrie were able to offer participants ideas, guidance, support, and, perhaps most importantly, protected time away from their campuses so they could work with their colleagues. In some cases, the support provided by MAC^3 made the interdisciplinary work possible. Only one participant said she would have done her QL project without MAC^3, and three were certain they would not have. Five indicated that interdisciplinary collaboration would have been possible on their campus but were not sure they would have carried out the work without MAC^3. As M6 put it, “MAC^3…helps you do it. It helps you, guides you. It helps you get going and pushes you.…It devotes specific time, and I think it’s good.”

As indicated by M6’s comment, the directors’ plan to provide faculty the time to work with their teams proved to be a valuable component of the multiday sessions. In addition to the optional workshops referenced earlier in this chapter, Linda and Carrie arranged for experts to share their experiences with participants. In this context, experts were community college faculty who had implemented their own projects. They were able to give participants ideas for what projects could be and help them avoid pitfalls. Seven participants described how the format of MAC^3 made interdisciplinary work possible and/or provided an incentive for doing it around QL. For example, M3 said that MAC^3 “was certainly a source of encouragement and an impetus for a couple of us to get together and formalize an idea and commit to finishing it off.…They gave us the concept and the space.”

Finally, as noted in an earlier section of this chapter, participants were also motivated by the fact that they were asked to present their projects before the end of the sessions. The protected time, support, and the expectation of a finished product ensured they were productive during their sessions.

Administrative support. Six MAC^3 participants described ways in which their colleges' administration and/or campus culture was supportive of their efforts to incorporate interdisciplinary QL. In some cases, support was financial; some colleges covered the $100 MAC^3 conference fee and travel expenses for participants. Financial support also took the form of stipends or reassigned time—essentially allowing instructors to replace part of their teaching loads with time dedicated to curriculum preparation or collaboration. M5 described this type of support:

> Well, it was kind of an initiative, a collegewide initiative that I think took off better on our smaller campus because it was easier to work in small groups and for a while. The administration also supported it financially by providing some stipends to work together to create the learning communities.

In some instances, *support* also had a less tangible meaning. Some participants described it in terms of approval, as opposed to the type of active support noted above. M2 captured a sentiment expressed by seven participants overall: "The administration's all for it. I suspect that things would be easier if there was much more actual support." As the reader can infer, this type of support is less effective in sustaining labor-intensive change on community college campuses. Given the importance of various types of administrative support, it is not surprising that lack of such support surfaced as one of the factors that limited implementation. This is examined further in the next section.

To summarize, MAC^3 did much to support participants, who were motivated by a holistic view of education and a desire to improve outcomes for at-risk students. Participant motivation was a key factor because of the grassroots nature of the work they did. The support MAC^3 was able to provide guided participants as they created their projects in a retreat-style setting and gave them protected time to create their materials. The colleges of some participants provided additional support by covering conference and travel expenses. Allowing participants to replace some of their teaching load with QL-focused curriculum development and collaboration was another way college administrators provided support.

Factors That Limited Implementation

While a college's administration can act in a positive way to support interdisciplinary work, some participants identified insufficient support as an obstacle. Other limiting factors related to faculty attitudes about math, financial considerations tied to the expense of the model promoted by MAC^3 as well as to compensation for faculty for the additional work required to incorporate QL into various disciplines. I begin below by continuing the discussion regarding administrative support.

Insufficient administrative support. That administrators were less than supportive surfaced in the external evaluation that was submitted to NSF (Gilliland, 2010). The last grant-funded winter institute was held in 2008. In 2010, the external evaluator wrote that one-fourth of MAC^3 projects saw only one term of implementation, citing administrative barriers.
Based on comments made by six MAC^3 participants in the current study, administrative barriers were not due to acts of commission but rather acts of omission. More precisely, administrators did not promote interdisciplinary QL at the campus level. At times, interdisciplinary work was the focus of meetings, but plans were not carried out. Likewise, administrators did not clear logistical hurdles for faculty. M11 said, "Administration can help if they wanted to push harder. They could have pushed it through, so I could see that they just didn't have the interest or desire or didn't see the importance at that time." M9 articulated how administrative support was insufficient:

> So anyway, yes, they [admin] were supportive, but was anybody helping us try to figure out why our classes were not connecting[7] and trying to encourage us to continue to do the learning community? No.

The story here is that encouragement is not the same thing as support. There are various reasons why this support may have been lacking, including financial constraints, statewide initiatives that take precedence, or projects that are more important to top-level administrators. As M5 put it, "[W]e'll put our money and our time where our values are, and so we don't communicate a whole lot of value in across-the-curriculum stuff if you're not willing to give faculty money and/or time to do it." Without proper administrative support, an initiative cannot take hold and spread across a community college campus.

Math-avoidant faculty. Both directors noted that some MAC^3 faculty had personal obstacles to overcome—in particular that some MAC^3 participants had been math avoidant. For example, Linda noted, "[T]here really were faculty who were non-STEM who were very anxious about mathematics.…It was interesting to learn that these are academicians and that that math anxiety that pervades our culture indeed does pervade our culture." This raises the question of how many faculty never attended MAC^3 for this reason. One participant said that, in fact, he would not have attempted to incorporate quantitative content into his social science discipline without the support of MAC^3. Those faculty who did attend MAC^3 and experienced math avoidance were not necessarily equipped to teach the mathematical content as it came up in their new curricula. Thus, they needed additional support after they left MAC^3. This is further discussed later in the chapter.

Need for and expense of the learning community model. Linda indicated that one of the things MAC^3 directors learned early on as a result of their work on their own campus and

[7] "Connecting" in this context refers to linked courses, further discussed in the next section.

with the original MAC grant is that after faculty created their projects/curricula, they often faced difficulties in the classroom as they delivered mathematical instruction. In fact, she said that the difficulty instructors found when they taught the math was the biggest obstacle non-math faculty faced. They learned that successful implementation meant having a math teacher present in the non-math class to teach the math content, at least for the first round of implementation. Optimally, a two-teacher team partnered to teach two linked courses. This is sometimes referred to as coordinated studies or a learning community, and it is the model promoted by MAC^3.

Some participants knew this was not possible because, as Carrie noted, the mechanism for linking classes "didn't exist at their school." For those who were able to link courses, the issue became cost. Four MAC^3 participants (one of whom was M11, whose project was never implemented) mentioned the cost associated with running a learning community. Said M7, "It was too expensive to run. So the way that we teach those courses, if there's two teachers in a classroom, it costs twice as much money." Thus, the learning community model itself was perceived as unsustainable.

Lack of compensation for faculty. Formally linking courses was only one way to foster the kind of collaboration envisioned by MAC^3 personnel. An alternative model used by some participants simply had faculty collaborating over curricula and/or dropping in to one another's classrooms as needed. Collaborating and incorporating quantitative content in non-math courses requires that faculty do additional work, and so compensation became an issue. Five MAC^3 participants indicated that faculty need to be compensated if they are to be expected to continue putting in the required extra time and effort. As M4 said, "I think there's an interest all around in collaborating, but the issue also is compensation. And in this day and age, it is a significant portion of the agenda." Noteworthy is that this participant continued collaborating with her colleague because she believed in the work and felt it was valuable enough to continue. The work stopped when she became an administrator, but she indicated that she was about to return to the classroom and resurrect the project.

Thus, my finding is that the faculty who had a sustained, ongoing focus on QL in their courses did so so on their own initiative. They were not the result of campuswide support, as campuses were not willing or able to provide sustained support. Learning communities largely came and went or were never implemented at all. Some QL efforts ended when faculty members left the classroom, whether to retire, to become administrators, or to relocate to different campuses with different characteristics. Sometimes, administrative turnover or a change of campus focus meant support for interdisciplinary QL efforts waned.

Below, MAC^3 is explored in more depth as I present its successes and obstacles. I close the chapter with a discussion of how obstacles can be overcome and what participants indicated would be necessary for a sustained interdisciplinary QL program on a community college campus.

MAC^3 Successes and Obstacles

According to interview participants—faculty participants and the MAC^3 directors—as well as the MAC^3 evaluation document, MAC^3 was successful in several ways. It exposed faculty and students to QL, and this exposure in turn had a positive influence on both faculty and students.

Measures of Success

Broad exposure. The aim of the MAC^3 project was to support community college faculty in various disciplines who wished to incorporate quantitative content into their courses and to do so on a national level. Linda and Carrie both pointed to increased exposure to and awareness of QL when describing the successes of MAC^3. Linda noted that "158[8] faculty, 59 interdisciplinary teams, and 36 colleges from 19 states" participated in five MAC^3 summer and winter institutes. According to the evaluation document, at least 80% of the faculty teams used their projects at least once on their campuses, with an estimated 2,000 students affected overall. (This estimate is based on the number of surveys that were completed by students in MAC^3 courses.) Additionally, Linda and Carrie coordinated 13 traveling workshops (Gilliland, 2010). Such exposure is admirable as an outcome. Mere exposure would do little, however, to achieve MAC^3's greater vision of a "mathematically literate society" (Gilliland, 2010). For that to occur, that exposure must have lasting effects on students and faculty.

Student perceptions and outcomes. Given the teaching mission of community colleges, a program, class, or project that positively influences student perceptions and outcomes is arguably a successful one. Among the characteristics of QL is a disposition to use math to inform decision making. One measure of success for MAC^3 is that students in MAC^3 classes had positive attitudes towards math and saw math as relevant. Seven MAC^3 interview participants said something to this effect. It was also referenced, directly or indirectly, by both MAC^3 directors. Finally, pre/post surveys administered directly to students reflected a positive change in their perceptions about math.

MAC^3 participants spoke of students being empowered or re-energized by their ability to do math. M6 captured the sentiment of four participants in saying, "It made [math] relevant for them, too.…Math is more relevant and applicable…to the world and to everything they were doing, to their other courses." This quote touches on a key component of QL—the ability to solve problems in authentic contexts. Seeing how math interacts with other disciplines is key to

---

[8] This number differs from the 179 attendees referenced in Chapter 3 because the MAC^3 website included attendees of the original MAC program.

helping students see that the ability to do math is a transferrable skill. Based on the results of 1,008 pre/post surveys administered to students, the external evaluator concluded, “After completing a MAC^3 course, surveyed students showed statistically significant gains in their interest and confidence in mathematics, their awareness of math in their lives, and their appreciation for interdisciplinary learning” (Gilliland, 2010). Both directors indicated that students in MAC^3 classes did not ask when they would ever use the math they were exposed to in these classes. This alone is a worthwhile outcome.

These improved attitudes about math are accompanied by improved learning outcomes for students. Four MAC^3 participants indicated that student success and retention improved in their MAC^3 classes. M5, whose team was motivated by improving outcomes for basic skills students, spoke of what her school data showed regarding students in that school’s learning community: “It was striking and statistically significant how much more successful these students were than students in standalone sections.” Three other MAC^3 participants made similar statements based on data. Of note is that all four of these instructors implemented the learning community model that proved to be unsustainable. Ultimately, for participants whose goal was to help students see the relevance of math and to improve success and retention, this work was successful—if only for a time. Perhaps a more lasting effect was on the faculty participants themselves.

Benefits to faculty. The faculty who participated in MAC^3 described several areas in which they were positively affected by their experience. Six identified benefits of working with faculty in different disciplines including a better understanding of what they experience. There was cross-pollination as a result of collaboration and sharing ideas. For new faculty members, MAC^3 was a chance to understand the philosophy of community colleges. Two participants specifically said that they learned what a true learning community looks like.

In what was a minority voice, M1 told of how his experience with MAC and MAC^3 impacted the trajectory of his career and view of interdisciplinary work: “I really think that having had the MAC program at that crucial point in my development gave me the vision for what’s possible.” He was able to apply his experiences in creating QL projects to build a service learning program on his campus that continues to this day. While this service learning program does not focus on QL, some of the student projects do have quantitative components. M1 pointed to this robust program as a direct result of his work with MAC^3.

The work done in the service learning program contributes to civic projects and other off-campus entities in the area. M1 said, “Because we use our Center for Service Learning as a base for a lot of our undergraduate research projects, it involves faculty from a considerable range of disciplines.” Faculty on M1’s campus can either guide students through projects for class credit or refer them to a service learning website that serves as a repository for project ideas. In the latter case, students participate in service learning by way of making a contribution to the community. Even though this program is indirectly related to MAC^3, according to M1 it has its roots in his earlier experience with the initiative.

Echoing the participants’ own accounts, both MAC^3 directors identified the impact MAC^3 had on faculty as a success of the program. According to Carrie, this aspect was not part of the original goal of MAC^3 but was an unexpected positive outcome. In addition to the offshoot discussed above, six participants experienced a positive change with respect to their own perceptions, strategies, and/or awareness of QL in particular and interdisciplinary work in general. As mentioned earlier, some faculty had been math avoidant; MAC^3 provided them support to overcome their avoidance and learn how to address quantitative content in their disciplines. Carrie described how that math avoidance was manifested:

> [T]hey shied away from any mathematics and even any numbers if they saw any statistics in an article they were reading. They just skipped right over it and let their students just skip right over it and not even think about, "What does this number mean?"

Carrie went on to say that MAC^3 participants stopped skipping over such content and became more intentional about how and when they incorporated math into their curricula. M1 noted, "I've been a little more intentional. I say, 'Okay, how can I integrate mathematical activities into the classes?'" Intentionality impacts how instructors select projects or curricula for their students in a way that adds to students' QL. Some also noted that they had learned to break larger projects into smaller pieces to make the work more doable for students. This lasting effect on the faculty who participated in MAC^3 goes beyond the aforementioned measured impact on students, because these pedagogical changes will also touch current and future students throughout a faculty member's career. Viewed through this lens, the positive impact on faculty is perhaps the strongest legacy of the MAC^3 project. Having considered the successes of MAC^3, I now turn to the obstacles that affected the program.

Obstacles to Success

Logistical issues. Much of the work Linda and Carrie did under the MAC^3 grant was informed by their earlier work on the EdCC campus and by the original MAC grant. The MAC grant was a matching grant, meaning that Linda and Carrie had to raise money to match the amount awarded by the NSF. They were the co-principal investigators (PIs) on the MAC grant and had a large degree of autonomy in carrying out the work. For the national dissemination MAC^3 grant, however, AMATYC was the funded agency, and Linda and Carrie were no longer the PIs. The result was that they now had to answer to AMATYC and seek approval for each summer and winter institute and traveling workshop.

Said Carrie, “Before, we had pretty much been able to create our own stuff and work on our own timelines, and we were pretty self-sufficient, whereas with AMATYC we had a new set of eyes of people who wanted a say.” Linda and Carrie had to hire and work with support staff who were geographically distant and sometimes did not share their vision. Communication with geographically distant personnel presented a new challenge. Carrie explained: “It became more work to delegate the work than to actually just do it.” Gaining approval from AMATYC was an added layer that required additional attention. These logistical issues were obstacles they had to overcome to carry out the work they had planned.

MAC^3 participants also identified logistical challenges. It can be challenging to find class time to fit in additional content. The curricula in college courses is often dense, and it can be difficult to incorporate additional material that is not viewed as essential. M2’s voice is representative of three participants. He had been enthusiastic about incorporating QL into his social sciences course, but he also told me, “I’ve got so much stuff to cover. Where do I and what do I?…We all have this problem.” One can see the dilemma faced by this willing participant. He found ways to address QL by looking for natural fits within his discipline, but doing so came with challenges. It is easy to see how this obstacle might be viewed as insurmountable by a reluctant individual. Other logistical challenges related to learning communities themselves. M9 said her college was not able to link the two courses in her learning community: “we always had difficulties scheduling it in the system…so that we had the same students. I had done other learning communities at the college on and off, but for some reason…we couldn't get it connected properly.” M11 pointed to advisors as obstacles. She said, “the advisors would not push this learning community…we didn’t get the help” that would have been necessary to execute her project.

Sustainability. Sustainability affected MAC^3 efforts in two ways. First, some faculty knew, prior to attending MAC^3, that they would not be able to use the learning community model and they therefore scaled projects to work within existing frameworks on their campuses. In some cases, this was a campus issue; for some, it was a statewide issue. As Carrie noted, "A lot of states did not have that.…[Participants] wanted to co-teach it. There literally was no way to, say, at registration, have the students sign up for this class and this class consecutively or simultaneously." Faculty attendees were stymied because the model they saw at MAC^3 was attractive, but they knew they could not get such creative courses off the ground on their campuses. And, as stated in an earlier section, those who did eventually saw them come to an end.

Second, as the NSF grant came to a close, sustainability beyond the MAC^3 grant proved problematic. The original plan was to use AMATYC's traveling workshop network to continue to offer professional development to community college faculty across the country. Both directors said that once the funding stopped—when attendees had to cover the entire cost of the workshops—the workshops died out; people stopped requesting them shortly after grant funding ended. This proved to be a learning experience for the directors. Linda explained that when MAC^3 was created, she and Carrie did not build in a plan to continue the work after the expiration of the grant. She spoke of this as an incomplete planning process: "[T]he sustainability piece was lost.…We were just planning two-thirds, and then thinking the other third [that of continuing the work beyond the grant] would kind of take care of itself or we'd figure it out." Linda said she now builds such planning into her projects in the beginning stages. This kind of vision is one way in which such an obstacle can be overcome. In the next section, I examine how other obstacles were or might be handled for a sustained interdisciplinary QL effort on community college campuses.

Responses to Obstacles

Administrative support. Administrative support was discussed earlier in this chapter as a factor that supported implementation of interdisciplinary QL curricula. In that section, some of the administrative support described was simply approval, rather than active support. The type of administrative support that participants described as being necessary for sustaining interdisciplinary QL efforts is more structured in nature. I asked interview participants to speculate about what would be required to implement and sustain a QL initiative on a community college campus. Based on comments from five MAC^3 participants, the key types of support are administrative buy-in; an ongoing reward system (such as stipends or reassigned time) for faculty who are leading and participating in the effort; incorporation of curricula—particularly linked courses—into the schedule of classes; and a budget line that references the initiative. As Linda put it, "Your administration [needs to see] this as part of the mission of the institution." Carrie indicated that having a course "on the books" was one way to ensure that the initiative could continue despite administrative and faculty turnover.

M1's experience with the service learning program on his campus bore out some of these recommendations. His example shows how administrative support in the form of reassigned time can support faculty in interdisciplinary endeavors. He indicated that he has, at times, had to push back against administrative efforts to scale back the program; incoming administrators have not always shared the vision of their predecessors. Despite this obstacle, M1 has been granted one-third reassigned time to do the work required to sustain the service learning program. Without this reassigned time, he would not be able to support the robust program he developed. As part of his full-time contract, he is paid for time to administer this program, which is to the benefit of students and other entities local to his campus. As he put it, “What that does is give me the time to collaborate with my colleagues to do training, pursue grants, pursue contracts and…engage directly with community organizations.” It is evident how this kind of attention would be valuable in sustaining an interdisciplinary QL effort.

Additional administrative support could be in the form of stipends, professional development opportunities, infrastructure, or logistical support. As stated earlier in the chapter, compensation was identified as a limiting factor. Stipends are a way to compensate faculty for the time it takes to develop curricula or for providing assistance to one another. Asking community college faculty to teach content in a discipline that is not their area of expertise without offering support can be problematic, to say the least: “There needs to be support for when things fail” (M2). This is also where professional development can come into play. Professional development can provide tools for faculty to develop and deliver quantitative content. An additional professional development topic might be finding appropriate QL materials, which can be challenging, as three participants indicated. Although this is a minority of participants, identifying obstacles is the first step in overcoming them. Finally, lack of infrastructure and lack of logistical support were identified as problematic when participants discussed linked courses. By clearing this hurdle for faculty, administrators can pave the way for interdisciplinary QL.

Faculty buy-in. Administrative buy-in is necessary; so is having a base of faculty who are willing to do the work required to ensure QL is incorporated across a community college’s curriculum. Faculty members are the ones on the ground, so to speak. Eight faculty participants and both MAC^3 directors pointed to the need for faculty buy-in in sustaining an interdisciplinary

QL effort. Faculty and administrative turnover can lead to the abandonment of an initiative, particularly if it rests on the shoulders of a single individual. M4 represented the voices of 10 participants who said that what is needed are “people who are respected faculty, et cetera, senior leaders who are also respected, but faculty in particular who are respected, to help be those advocates of a quantitative literacy program.” Faculty and administrators together can be the vehicle for changing a community college’s culture to one that focuses on quantitative literacy.

A supportive culture. The most successful efforts I was able to find were the result of faculty tapping into existing campus structures. M4, whose project was active for as long as she was in the classroom, had a culture of collaboration on her campus. M1’s service learning program has served as a nexus for faculty and could be a vehicle for QL for faculty with an interest in it; by encouraging students to participate in service learning, faculty can promote QL, depending on the projects they choose to emphasize. On M7’s campus, learning communities were already in existence and in fact continue to this day. His QL learning community lasted for three years before the administration promoted others. That he was able to implement the QL learning community at all speaks to the value of having the pre-existing opportunity.

Quantitative Literacy Work Outside of MAC^3

When Linda and Carrie created MAC and MAC^3, they were at EdCC, so it comes as no surprise that there were other faculty on that campus who included QL in their courses. Among them were M1 and M2. Because of the connections M1 made through interdisciplinary work on his campus, he was able to put me in touch with four of his colleagues who incorporated QL in their courses outside of the MAC^3 initiative. I identify these participants as N1 through N4. N1, N2, and N3 taught STEM disciplines, and N4 taught English. They have all taught their respective disciplines for over 10 years. I do not give specific lengths of experience in order to protect their anonymity. For the same reason, I also do not include the specific STEM disciplines they taught.

Even though, as indicated in Chapter 2, quantitative literacy is considered separate from traditional mathematics for STEM students, I include N1, N2, and N3 because based on what they told me, they have incorporated QL into their curricula. For these STEM faculty, QL takes the form of representing, analyzing, and interpreting data. Their students also perform computations, which is to be expected in STEM courses. N4 is a contrasting example, showing how different aspects of QL can fit in to a non-STEM discipline.

The components of QL in these four instructors' classrooms are presented in Table 12. I have included M1 and M2 in the table because they also taught at EdCC. However, in most of the discussion that follows, I do not include evidence from M1 and M2, as their feedback was presented earlier in the chapter. Thus, the discussion here mainly focuses on N1 through N4.

Table 12

QL Components Identified by EdCC Faculty Participants

	M1	**M2**	**N1**	**N2**	**N3**	**N4**	**Total (n = 6)**
Complete straightforward estimations and calculations	**x**	**x**	**x**	**x**	**x**		5
Complete calculations to answer meaningful questions	**x**			**x**			2
Analyze/make judgments based on quantitative information	**x**	**x**	**x**	**x**	**x**	**x**	6
Solve quantitative problems in authentic contexts and everyday life situations		**x**		**x**		**x**	3
Represent quantitative information using words, tables, graphs, and equations	**x**			**x**	**x**		3
Draw information from charts, graphs, and geometric figures	**x**		**x**	**x**		**x**	4

Communicate results for various purposes and audiences				x			1
Create sophisticated arguments using quantitative evidence				x			1
Develop habit of mind		x		x	x		3

All three of the STEM instructors talked about their students' use of Excel. According to N2 and N3, the analysis done in Excel mostly involved finding the mean and standard deviation of a set of data. A main difference between this analysis and what students would do in a statistics course is that the data with which students worked were based on their own measurements and experiments. For instance, N2 said, "So they'll do five different independent variables and they'll have five trials of each, and I show them, okay, you can go into Excel and…you can find the standard deviation."

N2 stood out from the field of participants in this study in that he was the only one who described students creating sophisticated arguments, an element from the AAC&U (2009) VALUE rubric. The prompt he gave his students was to create an argument that would convince the college's Board of Trustees or to perform a cost analysis for the efficacy of a proposed initiative. He indicated building communication skills as one of his aims as a teacher.

Based on the statements made by N1, N2, and N3, it is difficult to identify a pattern of QL elements in their students' work, other than that they all had students perform straightforward computations and make judgments based on quantitative information. N4, the English teacher, stood out in a different way. His students were the only ones who did not perform computations. This, again, is to be expected in an English class. Instead, he wanted his students to understand the data they found in print. He said,

> I'm not having students apply some sort of knowledge they would have learned in…an algebra class and abstraction from the real world or something like that. They're

> encountering math in some sort of real world context…The kind of math I'm dealing with in my classes is the kind of stuff that a layperson can understand and are in…newspaper articles or popular journals that are not intended for math specialists.

N4 saw the ability to understand and analyze data as part of being educated. In fact, five of the six EdCC participants indicated that QL is part of a complete education.

Just as with the other MAC^3 participants, EdCC faculty have experienced some obstacles in finding ways to address QL in their courses. Since these participants focused on what was happening in their own classes, however, the obstacles were different from those faced by MAC^3 participants who were building learning communities. For example, N3 and N4 indicated that one challenge was students' incoming math and statistics knowledge. N3 said, "They're much more familiar with the algebra.…Statistics has maybe some more idea than judgment in it.…It's hard to get them to look at a set of data and get that the variability of the data means something." For N4, the difficulty is in students' understanding of the data that are presented to them.

Regarding collaboration with other faculty on campus, N1 said that "currently at our college, we do not have a time where we can meet at a regular time, cross-departmental on a regular basis, and just communicate." N4 referenced the expense of the learning community model no longer in use at EdCC. In contrast, N2 said of the administration, "they definitely support collaborations. Every time I've discussed it with an administration person, they're very supportive of it, just to say, 'Hey, that's really cool. You should keep doing that.'" This is reminiscent of how MAC^3 participants described encouragement as support. N2 also said, "There's no incentive or pressure or anything like that. No carrot or stick." N4 echoed this, characterizing the administration as demonstrating "benign indifference."

Earlier in this chapter, I discussed how MAC^3 participants' motivation was a key factor in their interdisciplinary QL work. I presented stories that demonstrate how persistence led to continued QL content in individual instructors' classrooms. This persistence is characteristic of the EdCC faculty participants as well. They believed strongly enough in the need for QL that they incorporated relevant content where they could, though they did so without collaboration or additional compensation. Like MAC^3 participants, the EdCC faculty members in this study found ways to address QL in their courses. Though they did not participate in MAC^3 themselves, they had a connection to it through their colleague, M1. Their experiences provide an example of how the lasting effect MAC^3 had on one participant can in turn affect others. Their stories also provide a fuller picture of what QL can look like across the curriculum—in STEM and non-STEM courses—when teachers find it to be of value. N4 gave some insight that encapsulated what the EdCC participants said to me. When asked whether math should be taught only in math classes, he replied, “I would say it’s kind of like saying writing should only be taught in writing classes. That’s not helping students learn how to be holistic thinkers.” In a nutshell, N4 captured the spirit of quantitative literacy.

Chapter Five:

Discussion

The story of quantitative literacy told in this study is one of individual efforts and persistence. Participants' motivating factors paint a picture of dedication to the cause of improving QL. In many cases, they attended MAC^3 with the support of their superiors. Some colleges even footed the bill for travel costs and conference fees. And while most projects thence created were used at least once, virtually none of the people I talked with were able to use them in the long term. For some, however, the QL legacy has lived on within the walls of their own classrooms.

Make no mistake: This is admirable, and over the past decade, the efforts of these individuals have doubtless touched many students. On the other hand, absent a larger initiative, the QL curricula currently in use will retire with the faculty who are using them. A much greater impact would result from lasting change in the form of institutionalization. With all of this in mind, this chapter opens with a discussion linking the findings to the literature. Then I discuss additional insights before I present implications for practice. I address limitations of the study and then close the chapter with recommendations for future study.

Connections to the Literature

In reviewing the obstacles identified in the extant literature that I presented in Chapter 2, I found that there are various degrees of agreement with the findings of this study. This section is broken into three subsections: (a) obstacles from the literature that appeared in my findings, (b) those that are peripheral to the findings, and (c) those that did not surface in this study.

Findings that Support the Literature

Obstacles that were present in the extant literature that were reinforced by the findings of this study include the siloed nature of college campuses, the importance of generating buy-in, the role of administrators, developing QL curricula and finding QL materials, the limitations of non-math faculty when teaching math, the diversity of students' mathematical backgrounds, and funding issues. I address each of these in turn.

The siloed nature of postsecondary institutions. If not for the siloing that occurs on college campuses (Carnevale & Desrochers, 2003), the interdisciplinary nature of the teams that attended MAC^3 would not be of interest. That is, if interdisciplinarity was "practice as usual," there would have been little motivation for this study. One of the positive outcomes of MAC^3 was that it was successful in bringing together faculty from various disciplines. Previous research by Carnevale and Desrochers (2003) described departmental specialization as a barrier to interdisciplinary efforts. That the discipline of math exists mostly in a silo—detached from other curricula—obscures the practical value of the discipline, thereby limiting its accessibility to students.

The participants of this study and of MAC^3 more generally were able to overcome the "within discipline" barrier by working collaboratively, and they were motivated to do so. Indeed, some identified the opportunity to break through the interdisciplinary barrier as a key motivating factor. Accordingly, their motivation to develop and implement MAC^3 projects was a major finding of this study. The silos were again evident for most of the study's participants when support was withdrawn for the learning communities they created. This interdisciplinary barrier remained for most of the participants of this study.

Generating buy-in. Participant motivation was a strong factor for success, pointing to the power of "buy-in." In all cases examined in this study, buy-in on a larger scale was difficult to achieve and maintain, and this is supported by previously published works. For example, Steen (2001a) asserted that the public has shown little concern for numeracy. He asserted that generating interest for QL in the face of, for instance, existing standards in education is a challenge to changing the status quo. At the same time, the participants in this study showed interest in increasing QL on their campuses, so there was some buy-in at the grassroots level. However, they were unable to generate campus-level buy-in. After many participants' projects had run their course, their campuses returned to the previous state of affairs regarding interdisciplinary QL. I found no case of a community college where QL was a focus across the curriculum. That is to say, while MAC^3 participants were able to get colleagues on board, at least for the time it took to attend and implement their MAC^3 projects, they were not able to effect large-scale implementation. The grassroots efforts did not take root and grow. Absent some sort of incentive—monetary, reassigned time, etc.—campus initiatives simply did not spread beyond participants' classrooms.

What came up time and again in my interviews was that for a QL program to see widespread implementation, a community college would need a strong faculty base to do the required work and support their colleagues as they tread these waters. Considering that the majority of the MAC^3 participants in this study pointed to the need for faculty buy-in to sustain a QL initiative, it is reasonable to assume that generating faculty buy-in remained an obstacle.

Another obstacle QL change initiators faced was generating administrative buy-in. Steen's (2001a) statement about the difficulty in changing the status quo included leaders in education. In the context of the current study, campus leaders include both faculty and administrators. The theoretical framework of convergence, presented in Chapter 2, shows that these two groups need to work together if campuswide change is to be successful. The importance of convergence is discussed in more detail later in this chapter; first, I consider how the current findings reinforce the need for administrative buy-in.

Administrators. Korey (2010) wrote that some MAC^3 participants returned to their campuses to find that administrators were unsupportive of their QL work. It follows that getting administrations involved in QL work would remove an obstacle, allowing participants to put into practice what they developed at the workshops. Ultimately, whether a MAC^3 project was implemented—and for how long—was determined by decisions made by administrators, particularly in the case of learning communities. As long as their campuses supported the learning community models, participants were able to carry out the work that was the focus of this study. It was a recurring theme in this study that when the administration pulled support, participants' projects came to an end—assuming that the project had actually been implemented in the first place. M11, one of the participants whose project was never implemented, was left wondering why her college had sent her to MAC^3 if there was little intention or motivation to then support the actual implementation of the project. It was strikingly clear that without the support of a college's administration, across-the-curriculum impact was very difficult if not impossible.

Developing curricula and finding materials. QL is a nebulous concept, as indicated by the various definitions presented in Chapter 2. It can be a challenge to know what aspects to address in a particular field and how to do so. One way to help faculty overcome this challenge is to provide them with curricula and materials that they can readily use in their classes. QL materials are not widely available, perhaps because of some of the obstacles identified in this study (e.g., the specialized curricula in higher education and the lack of interest in interdisciplinary QL). Van Peursem, Pietrzak, Wagner, and Bennett (2012) reported that finding QL materials is a challenge. This difficulty is also suggested in Steel and Kiliç-Bahi's (2008) article on how a small liberal arts college chose to address QL on its campus. In both cases, faculty had to develop their own materials. MAC^3 participants faced the same challenge.

One reason MAC^3 was viewed as so successful by its participants was that the multiday workshops provided them protected time to develop curricula and materials. Participants spoke of the power of working in groups and having time to think or to put a syllabus together. Some specifically identified finding appropriate materials as a challenge. All of this speaks to the necessity of having support to develop appropriate curricula, which would not have been an issue if QL textbooks were as ubiquitous as algebra textbooks are.

One takeaway is that a plan to address QL on a community college campus needs to take into account the dearth of readily available materials. Another takeaway is that some of the work in this area has been done. It is a success of MAC^3 that AMATYC hosts a website that has served as a repository for materials created in various institutes that were funded by the grant. If QL is to be a focus across the curricula of community colleges, faculty will need continued support in this area. MAC^3 has made a tremendous start; more work is needed to remove this as an obstacle on campuses across the country.

Limitations of non-math faculty when teaching math. Two of the originators of the QL initiative in the United States have argued that faculty readily admit that they are not quantitatively literate (Madison & Steen, 2009). The current data support this assertion. At least one MAC^3 participant and both directors reinforced the notion that educators face the same challenges with mathematical content that students do. MAC^3 addressed this by recommending that math instructors be present in non-math classes for at least the first round of implementation. This may not be practical in every case. At the very least, an effort needs to be made to educate non-math faculty so that they can become quantitatively literate. One of the directors indicated that as faculty participants became more familiar with the quantitative content they encountered, they were less likely to shy away from it. With knowledge comes confidence, and that knowledge can come from specific supports. One participant's quote comes to mind: "There needs to be support for when things fail" (M2).

Diversity of students' mathematical backgrounds. One challenge that arose in this study relates to the various levels of mathematical ability of the students. More specifically, participants said they had to assume that students had varied knowledge related to statistics and quantitative content. This is important for two reasons. First, the finding reinforces what was in the literature. Introductory and general education math courses are described as difficult to teach, in part because they comprise students with varying levels of incoming mathematical ability (Barker et al., 2004). This study did not focus on general education math courses, but it did involve including mathematics in general education courses, and the finding echoes what is in the literature. The second reason is more practical. If community college faculty know this is a potential issue, they can plan for it. They can prepare a brief review/preview of the quantitative content their students will encounter and ease the transition into quantitative content in non-math classes. Without any preparation, it is easy to see how such content could be a rude awakening for instructors and students alike.

Funding issues. A recurring theme in this study's findings is that sustained QL initiatives need financial support. Learning communities were discontinued because they were expensive; faculty participants identified compensation as a necessary component of an interdisciplinary campus initiative like QL. Absent stipends, compensation, reassigned time, or dedicated funding, the interdisciplinary projects of almost all of this study's participants came to an end. In an article comparing QL with writing across the curriculum, Hillyard (2012) described across-the-curriculum movements as expensive, as this study's findings bear witness. One participant stated it well: "[W]e'll put our money and our time where our values are" (M5). If QL is to be a focus on community college campuses, initiatives need to be institutionalized; college budgets need to include a category that provides support for QL initiatives. This is not to say that throwing money at the problem will make it go away. But if colleges are intentional about providing financial support for QL initiatives, many of the above obstacles can be addressed in meaningful ways.

Findings in Partial Agreement with the Literature

Sustaining collaboration. Some of the current findings relate to the findings in the extant literature but, for various reasons, do not completely align. The first relates to difficulties finding time and faculty who are willing to collaborate (Rogotzke et al., 2010). The participants in this study made time to collaborate with their colleagues. Thus, MAC^3 did address this difficulty. However, their experiences indicate that collaboration is difficult to sustain, and these collaborations did not continue. None of the participants said they could not find willing partners; what was lacking instead was persistence in their collaborative efforts. It was also evident that time was a factor. Participants speculated that paying faculty for their time to develop materials and to continue to plan and implement learning communities was required for a QL effort to take root. On the other hand, when participants truly saw the value in QL, they made time to continue using their curricula in their own classes. This leads into another time issue—one related to faculty reluctance to devote the time necessary.

Reluctance to make time. One obstacle identified in the literature is a reluctance on the part of faculty to give up course time to incorporate additional content (Hughes-Halett, 2001). Participants in the current study did not discuss resistance in this way. Rather, participants said they were limited as to how much QL content they could incorporate due to the time constraints they were facing. This was partially addressed when instructors found natural places to bring in quantitative material; that they found ways to do so is contrary to the reluctance referenced by Hughes-Hallett. Nevertheless, shoehorning additional content into an already full course outline does present challenges.

Advising. As indicated in the previous section, one way in which administrators can provide support is by clearing logistical hurdles. I have included advising in this section because, while Todd and Wagaman (2015) discussed challenges to staff and advisors, I did not speak with staff or counseling faculty to learn what obstacles they might have identified. What I learned is more along the lines of identifying advisors themselves as obstacles, though this was only referenced by one participant. Part of M11's difficulty was that advisors were not able to inform students about new course offerings. Thus, challenges related to advising arose as an issue of partial alignment with the literature.

Spreading change across departments. The participants in this study did not directly attempt to spread change to other departments but instead they participated in interdisciplinary collaboration. However, according to the data I collected, attempts to do so would likely have been problematic. Seymour (2002) identified this as a challenge to interdisciplinary efforts in general. Considering some of the obstacles above, it is clear that a faculty member's attempt to effect change in a department other than her own could be difficult. She would need to break through silos, generate buy-in, and find time to collaborate, at the very least. When one considers all of the challenges identified above, it comes as no surprise that this study did not reveal any campuswide QL initiatives.

Obstacles Identified in the Literature But Not Found in This Study

Several challenges that were identified in the literature did not come up in this case study. I present these literature-based obstacles here and speculate as to why they did not appear in the current data. First, there was no discussion of turf wars or who should lead change efforts (Hughes-Halett, 2001; Madison, 2012), perhaps because participants attended MAC^3 with willing partners. On one hand, math faculty are typically seen as responsible for starting QL conversations; on the other hand, some may question whether they are the right people for the job. In this study, math faculty were seen as having supporting roles for non-math faculty, and one of the directors of MAC^3 was herself a math instructor. The participants I interviewed all seemed to have taken ownership of QL, but not to the exclusion of other faculty. When funding for MAC^3 was pulled on some campuses, it may have been because funds were being reallocated. It is possible that this is the type of situation that has led to turf wars on other campuses, but none of the participants framed their experiences in this way.

Another finding in the literature that did not emerge in the current findings relates to faculty objections regarding watering down the curriculum (D. Cohen, 1995). It seems likely that these objections would be raised by math faculty if they were being pressured to change their curriculum. Since I studied processes by which non-math faculty, with the help of math instructors, infused QL into their courses, it is reasonable that none of the participants in this study raised such an objection.

The difficulty of assessing QL is also discussed in multiple sources (e.g., Roohr, Graf, & Liu, 2014). Difficulties arise when attempting to assess interdisciplinary skills—it is difficult to know what to assess and in what context. That said, participants in this study did not bring up assessment. It is possible that QL assessment was viewed as a campus-level responsibility, albeit one that also occurs in particular courses. The point is that pressure to assess QL would likely come from the administration, and I would expect such pressure to be associated with a campuswide movement. This was not the case on the campuses of the participants I spoke with.

Finally, participants did not describe any resistance among their colleagues to administrative efforts, as was discussed by Seymour (2002). This is, again, not a surprise. In this study, I spoke with faculty about what were mostly grassroots efforts. While some had the encouragement of administrators to participate in MAC^3 and to implement their projects, they mostly responded to email invitations or heard about the initiative from colleagues. In recounting their experiences, they did not describe administrator-driven campus initiatives. Thus, there would have been nothing to resist.

Additional Insights

One finding came as a surprise, and that was the way participants described the benefits they experienced as a result of participating in MAC^3. This was also somewhat unexpected for the MAC^3 directors. On the one hand, MAC^3 was a professional development network, so its participants naturally grew as educators. But the benefits they described went beyond simply learning how to fit math into their disciplines. Some were energized by the quality of the MAC^3 institutes and described with joy the experiences they had. Non-math faculty became less avoidant of quantitative content; their perceptions changed as they came to terms with the value of QL. Beyond that, they spoke of developing an understanding of what their colleagues experience and of learning communities and interdisciplinary collaboration more generally.

I believe the most profound impact was the transformative experience of participant M1, who learned what was possible through collaboration. Without his MAC^3 experience, he may never have developed the service learning program that has helped shape his career. And while not directly focused on QL, that program serves as a nexus for faculty and can be a vehicle for work in various disciplines that can naturally include quantitative content. It is here that the essence of QL is realized. Finding math applications when considering issues that relate to wildlife and the environment must have an impact on the students who do the work. The experiences they have outside the classroom will have an impact on them. That they are having these experiences while serving their community likely makes it all the more real for them.

Another thing I took away from this study was how the participants talked about their experiences. Several MAC^3 participants were still excited about their work around QL even years later. I noticed this primarily in the participants who were still finding ways to address quantitative content in their courses. They discussed their MAC^3 experiences with an air of nostalgia and came across as truly committed to the cause of increasing their students' QL. This stands in stark contrast to one participant in particular—M10, one of the two participants whose project was never used, was mainly motivated by a desire to get a full-time job. Motivation, of course, does not tell the whole story. But I found the starkly different results connected to the vastly different motivating factors to be of interest.

Implications for Practice

The possibilities afforded by the service learning program at EdCC underscore one of the results of this study and lead to implications for practice. That is, if QL-minded faculty can tap into existing structures on their campus, they may face fewer difficulties getting their initiatives off the ground. This study was about incorporating QL into individuals' classes. Participants found natural fits between QL and their disciplines. Faculty and administrators alike can look for natural fits between authentically contextualized quantitative content and existing campus programs. In taking this approach, at least some logistical issues and structural barriers can be avoided. This, of course, does not address the issue of buy-in, nor does it mean faculty will automatically be ready to roll. Further work is needed.

As is evident from the findings of this study, the theoretical framework of convergence is particularly valuable in an exploration of interdisciplinary QL efforts. Convergence is characterized by faculty working with administrators to effect change (Kezar, 2012; Kezar & Lester, 2011). Kezar and Lester (2011) focused on change initiated by faculty who first recruited other faculty members to their cause and then worked to earn the support of administrators. Convergence was lacking for many of the participants of this study, though the data indicate that it is necessary. To the need for convergence, I would add the need for professional development. The implication is that whether starting from scratch or taking advantage of existing programs or initiatives, community college personnel who wish to undertake the work of addressing QL across their curricula would do well to consider three important components: faculty buy-in, administrative support (convergence), and professional development. I believe that addressing these three components simultaneously can be a recipe for success, not only for QL initiatives but for any interdisciplinary effort.

First, faculty buy-in is essential. Without it, change efforts will not extend beyond what was seen in this case study. One or two faculty members can lead the charge, but they need to start by building a support base. The progenitors of a change initiative can only do so much on their own. If they do not gain the support of their colleagues, they will experience fatigue and frustration. The sensemaking and sensegiving discussion from Chapter 2 can provide some support for this view (Kezar, 2012; Kezar & Eckel, 2002b; Kezar & Lester, 2011). As Kezar and her colleagues have found, it may make sense to start with pilot courses, then build a professional learning community, and then enlist administrative support at the right time. If an initiative rests on the shoulders of only a few individuals, it will die when those individuals leave the campus, whether because of a career or location change or retirement. Change may start small, but taking the long view means getting more people on board.

Second, as was referenced often by participants in this study, community college faculty need the support of administration. This can be especially challenging because the rate of turnover among administrators can greatly exceed the rate among faculty. Finding administrators who are sympathetic to or even enthusiastic for an initiative is key to institutionalizing the effort. One of the MAC^3 directors spoke of getting a course into the catalog, thus ensuring its continued existence. The same is true of larger-scale initiatives. Building initiatives into lasting programs, into the college catalog and into institution-level outcomes can ensure their continued existence irrespective of changes in administrative personnel. It seems paradoxical to enlist administrative support to protect an initiative against the whims of future administrators, but such foresight would surely be rewarded in the long run.

Finally, initiatives that require collaboration and innovative pedagogy, as QL does, require professional development. Arming faculty with dos and don’ts and giving them time to simply focus on their work was part of what made MAC^3 successful. With this in mind, I would argue that for a campus initiative to be successful, ongoing professional development is essential. However stable a college’s faculty and administration are, each campus hires new teachers and managers on a fairly regular basis because of growth and retirement. Unless new hires happen to have experience with the innovations, they will need information and support in order to achieve the mission inherent in the initiative. Whether faculty (new or veteran) are developing materials, learning pedagogy, or furthering the innovation, ongoing professional development can ensure that they continue to get the support they need. Further, such ongoing support keeps the initiative at the forefront of the college's activities. Together, the faculty and administration, with professional development support, can create a campus culture that embraces the values inherent in the initiative. In the context of this study, this three-pronged approach would lead to increased QL for faculty and students alike.

Limitations of the Study

As in any study, this one had its limitations. In this case, the limitations relate to the sample, the study design, and assumptions.

Sample

The sample was based on people responding to an email invitation and was therefore self-selected. Further, the faculty who attended MAC^3 ostensibly did so voluntarily. Thus, the results of this study cannot be extended to community college faculty members in general. Moreover, when I sent my initial email to the list of MAC^3 participants, it had been over nine years since the last winter institute. Due to the time elapsed, I may have missed contact with faculty who were no longer at their former institutions. These MAC^3 participants could have had stories of continued use of QL projects or a different perspective to share. With those who did participate, I very closely followed my interview protocols. I took advantage of opportunities to ask probing questions, but I inevitably missed some opportunities to gather richer description or go into more detail.

Design

Had I administered a survey to participants asking them to identify elements of QL that appeared in their students' work, Table 11 would have been more accurate. If I had administered such a survey prior to interviewing the participants, they might have been more able to recall details from the work they did when MAC^3 was active. Further, the study focused on MAC^3 participants and other faculty, not administrators. Two interview participants later developed administrative experience; however, my protocols did not ask for their views from the administrative perspective. Including this perspective may have shined more light on decisions made by administrators and might help contextualize the study participants' perspectives. I return to this idea in the section on recommendations for further study. Finally, the ideas I included for overcoming obstacles were largely based on speculation, not actual successes. That said, the recommendations made at the end of Chapter 4 are still reasonable in light of the evidence found in this study.

Assumptions

In considering my protocols, I'm confronted with two assumptions I made going into this study. First, because MAC^3 was an interdisciplinary experience, I assumed I would learn more about the collaboration component of the work. In fact, when developing the theoretical framework for the study, I considered social network theory (Daly, 2010), thinking that I would learn about how participants built their interdisciplinary teams and the logic that went into their decisions. The way participants discussed their work, however, did not put collaboration at the forefront. One participant said she would have worked with anyone; another said she invited a friend to go to Florida; yet another said that they had to bring a math person, so each time she went, she brought a different colleague (there was evidently faculty turnover on that campus).

Participants spoke at times of team teaching but focused more on what they did or what their students did than how they worked with their colleagues. I could perhaps have done a better job of unpacking the collaborative component of the faculty experience. It is also possible that since these participants' interdisciplinary partnerships did not generally see long-term implementation, the collaborative aspect of their work is not what stood out to them in their experience. I suspect that had I spoken with them 10 years ago, their partnerships may have played a more prominent role in their discussions.

Second, going into this study I assumed that, because MAC^3 started as an effort to address quantitative reasoning at EdCC, that campus would have had a wider interdisciplinary QL program. This view was bolstered when I first spoke with M1 while securing my sample. I now understand that he was able to connect me with several colleagues not because of the MAC^3 project but because of his own personal network. That said, the snowball participants he helped me find added a rich and valuable dimension to the findings. Having considered how this study might have been strengthened, I now turn my attention to how the QL discussion can be continued.

Recommendations for Further Study

I have four recommendations for further study. One theme that surfaced throughout this study is the influence administrators have over initiatives on community college campuses. With this in mind, it would be worthwhile to learn how to motivate administrative personnel to push for interdisciplinary QL in particular and other campuswide initiatives more generally. Faculty who know how to get administrative figures on their side will undoubtedly find more success than those who struggle with those who make campus decisions. At the same time, in keeping with the theoretical framework of this study—convergence of faulty and administrations—

finding ways to generate faculty buy-in would help ensure the success of interdisciplinary initiatives. For an initiative to take hold, a campus needs a critical mass of support on the ground—that is, from those whose day-to-day teaching might be affected. Thus, studying how to generate such buy-in would be of value.

My third recommendation is to learn best practices in professional development built around interdisciplinary QL. The MAC^3 directors built some dos and don’ts into MAC^3 once they learned what seemed to work and what did not. Adding to that body of knowledge would help arm faculty and administrators and would likely be useful in disarming naysayers. And fourth, this study focused on a professional development that promoted a particular format. Considering the difficulties that format posed for many participants, I recommend study of interdisciplinary QL models other than learning communities. Such additions to the knowledge base of successful practices would offer alternatives to those whose systems do not support or allow for linked classes and could allow for more dynamic learning arrangements.

Appendix A:

Study Information Sheet

UNIVERSITY OF CALIFORNIA LOS ANGELES
STUDY INFORMATION SHEET

Quantitative Literacy Across the Community College Curriculum: A Qualitative Case Study

Matt Henes (Tina Christie, faculty sponsor) from the Graduate School of Education and Information Studies (GSE&IS) at the University of California, Los Angeles (UCLA) are conducting a research study.

You were selected as a possible participant in this study because you teach at a community college and either currently include quantitative content in your course(s) or have in the past. Your participation in this research study is voluntary.

Why is this study being done?
The purpose of this study is to identify barriers and strategies associated with incorporating quantitative literacy across the community college curriculum. It is the goal of this study to increase across-the-curriculum quantitative literacy efforts and to aid those who wish to do so.
What will happen if I take part in this research study?

If you volunteer to participate in this study, the researcher will ask you to do the following:

- Respond to open-ended interview questions regarding your involvement with MAC^3 and your experiences in incorporating quantitative content in your course(s). Interviews will be conducted over the telephone or using a virtual meeting platform.

How long will I be in the research study?
Participation will take a total of about one hour for MAC^3 participants and two hours for MAC^3 directors. There may also be follow-up contact to ensure the accuracy of the data and its interpretation.

Are there any potential risks or discomforts that I can expect from this study?
- There are no anticipated risks or discomforts.

Are there any potential benefits if I participate?
You will not directly benefit from your participation in the research.

The results of the research may be of value to personnel at other community colleges who wish to increase their students' quantitative literacy by incorporating quantitative content in their own courses or across the community college curriculum.

What other choices do I have if I choose not to participate?
If you choose not to participate, no adverse actions will result.

Will information about me and my participation be kept confidential?
Any information that is obtained in connection with this study and that can identify you will remain confidential. It will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of using pseudonyms for participants. Interviews will be coded to mask their identities, except in the case of the MAC[3] directors, as their identities are known from existing literature. Interview transcripts will be stored on a password-protected computer and backed up using an encrypted cloud service. Interview transcripts may be printed for coding and analysis. Hard copies will be stored in a secure location to which only the researcher will have access. Any documents received will be stored in a secure location to which only the researcher will have access.

What are my rights if I take part in this study?
- You can choose whether or not you want to be in this study, and you may withdraw your consent and discontinue participation at any time.
- Whatever decision you make, there will be no penalty to you, and no loss of benefits to which you were otherwise entitled.
- You may refuse to answer any questions that you do not want to answer and still remain in the study.

Who can I contact if I have questions about this study?
- **The research team:**
  If you have any questions, comments, or concerns about the research, you can talk to the one of the researchers. Please contact:

  Matt Henes: mthenes@g.ucla.edu or (626) 585-7456
  Tina Christie (faculty sponsor): tina.christie@ucla.edu or (310) 825-2624

- **UCLA Office of the Human Research Protection Program (OHRPP):**
  If you have questions about your rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call the OHRPP at (310) 825-7122 or write to:

  UCLA Office of the Human Research Protection Program
  11000 Kinross Avenue, Suite 211, Box 951694
  Los Angeles, CA 90095-1694

Appendix B:

Interview Protocols

Interview Protocol for MAC^3 Directors

The interview will last approximately 90 minutes. You may end your participation at any time. With your permission, I would like to digitally record it so this interview can later be transcribed verbatim. The recording will not be shared with anyone else. If there are points during the interview where you would like me to stop recording, feel free to indicate that to me so I can turn the recorder off.

1. How long have you taught/did you teach at the CC level?
   How long at EdCC?
2. Do you believe quantitative literacy is different from traditional mathematics? If so, how?
3. Please describe your involvement with MAC^3.
4. What was done to build MAC^3 to a national network?
5. How did you recruit participants or how did they learn about MAC^3?
6. What was the format of the workshops or institutes?
7. What were the elements that supported its growth?
8. What successes did you see from MAC^3?
9. What successes, if any, did participants report as a result of embedding mathematical content in non-math courses?
10. In what ways, if any, was it less successful than you would have liked?
11. What obstacles, if any, did you face during its creation?
    Probe: How did you overcome them?
12. What obstacles, if any, did you face during its implementation?
    Probe: How did you overcome them?
13. What obstacles, if any, did participants report?
14. Since the grant had an end date, was there a plan was in place for the work to continue after the grant?
    Probe if there was a plan: What was the plan? Was it used? If it was used, what happened?
15. What would you say to the idea that math should be taught only in math courses?
16. What actions do you think are critical to starting a QL program on a community college campus?
17. What actions do you think are critical to sustaining a QL program on a community college campus?
18. Is there anything else you would like to add?

Interview Protocol for MAC^3 Participants

The interview will last approximately 60 minutes. You may end your participation at any time. Your identity will be kept confidential. Everything you discuss with me during this interview is strictly confidential. With your permission, I would like to digitally record it so this interview can later be transcribed verbatim. The recording will not be shared with anyone else. If there are points during the interview where you would like me to stop recording, feel free to indicate that to me so I can turn the recorder off.

For math instructors:

1. How long have you taught at the CC level?
   How long at your current school?
2. Tell me how familiar you are with quantitative literacy.
3. Please describe how you became involved with MAC^3.
4. What motivated you to become involved with MAC^3?
5. Please describe your MAC^3 project.
   Probe: How did the project you developed differ from traditional mathematics, if at all?
   Probe: Were you able to implement it? For how long?
6. Do you have any course materials you can send me (e.g., syllabi and/or assignment descriptions)?
7. Describe how you collaborated with your colleagues for this project.
8. Would this type of collaboration have been possible without your participation in MAC^3?
9. In what ways was your MAC^3 project successful?
10. What obstacles did you face in implementing your project?
11. In what ways, if any, has your college's administration supported or not supported your interdisciplinary math work?
12. What strategies, if any, have been successful in helping you to overcome obstacles to using an interdisciplinary approach?
13. Describe the role campus leadership—either formal or informal (like grassroots)—has played in your efforts to collaborate with other faculty.
14. In what ways did your students benefit from your participation in MAC^3?
15. In what ways, if any, have you benefited from participating in MAC^3?
16. What would you say to the idea that math should be taught only in math courses?
17. What actions do you think are critical to starting a QL program on a community college campus?
18. What actions do you think are critical to sustaining a QL program on a community college campus?
19. Is there anything else you would like to add?

For non-math instructors:

1. How long have you taught at the CC level?
   How long at your current school?
2. Please describe how you became involved with MAC^3.
3. Please describe your MAC^3 project.

   Probe: How did the project you developed differ from traditional mathematics, if at all?
   Probe: Were you able to implement it? For how long?

4. What motivated you to become involved with MAC^3?
   Probe: What motivated you to incorporate mathematical content in your course?
5. To what extent does the quantitative content in your class involve faculty from other departments?
6. Would this type of collaboration have been possible without your participation in MAC^3?
7. Do you feel that the math content students experience in your course differs from traditional mathematics? If so, how?
8. Do you have any course materials you can send me (e.g., syllabi and/or assignment descriptions)?
9. In what ways was your MAC^3 project successful?
10. What obstacles, if any, have you encountered in using an interdisciplinary approach to mathematical content?
11. In what ways, if any, has your college's administration supported or not supported your interdisciplinary math work?
12. What strategies, if any, have been successful in helping you to overcome obstacles to using an interdisciplinary approach?
13. Describe the role campus leadership—either formal or informal (like grassroots)—has played in your efforts to collaborate with other faculty.
14. What would you say to the idea that math should be taught only in math courses?
15. In what ways did your students benefit from your participation in MAC^3?
16. In what ways, if any, have you benefited from participating in MAC^3?
17. What actions do you think are critical to starting a QL program on a community college campus?
18. What actions do you think are critical to sustaining a QL program on a community college campus?
19. Is there anything else you would like to add?

Interview Protocol for EdCC Faculty

The interview will last approximately 60 minutes. You may end your participation at any time. Your identity will be kept confidential. Everything you discuss with me during this interview is strictly confidential. With your permission, I would like to digitally record it so this interview can later be transcribed verbatim. The recording will not be shared with anyone else. If there are points during the interview where you would like me to stop recording, feel free to indicate that to me so I can turn the recorder off.

1. How long have you taught at the CC level?
   How long at your current school?
2. Describe the math that students encounter(ed) in your course.
3. What motivated you to incorporate mathematical content in your course?
4. Do you feel that the math content students experience in your course differs from what they see in traditional math courses? If so, how?
5. Do you have any course materials you can send me (e.g., syllabi and/or assignment descriptions)?
6. To what extent does the quantitative content in your class involve faculty from other departments?
7. To what do you attribute your ability to collaborate in such a way (campus characteristics, etc.)?
8. What can you tell me about Building Community days?
9. What would you say to the idea that math should be taught only in math courses?
10. What do you perceive the are benefits to your students of incorporating quantitative content in your courses?
11. In what ways, if any, has your college's administration supported or not supported your interdisciplinary math work?
12. What obstacles, if any, have you encountered in using an interdisciplinary approach to mathematical content?
13. What strategies, if any, have been successful in helping you to overcome obstacles to using an interdisciplinary approach?
14. Describe the role campus leadership—either formal or informal (like grassroots)—has played in your efforts to include quantitative content in your courses.
15. What role, if any, has shared governance played?
16. Is there anything else you would like to add?

References

Agustin, M. Z., Agustin, M., Brunkow, P., & Thomas, S. (2012). Developing quantitative reasoning: Will taking traditional math courses suffice? An empirical study. *Journal of General Education*, *61*(4), 305–313.

Amey, M. J., Jessup-Anger, E., & Jessup-Anger, J. (2008). Community college governance: What matters and why? *New Directions for Community Colleges*, *2008*(141), 5–14.

Association of American Colleges & Universities. (2009). *Quantitative Literacy VALUE Rubric*. Retrieved February 12, 2017, from https://www.aacu.org/value/rubrics/quantitative-literacy

Attewell, P. A., Lavin, D. E., Domina, T., & Levey, T. (2006). New evidence on college remediation. *Journal of Higher Education*, *77*(5), 886–924.

Bahr, P. R. (2008). Does mathematics remediation work? A comparative analysis of academic attainment among community college students. *Research in Higher Education*, *49*(5), 420–450.

Bailey, L. J., & Stadt, R. W. (1973). *Career education: New approaches to human development*. Bloomington, IL: McKnight.

Bailey, T. (2009). Challenge and opportunity: Rethinking the role and function of developmental education in community college. *New Directions for Community Colleges*, *2009*(145), 11–30. https://doi.org/10.1002/cc.352

Bailey, T., Jeong, D. W., & Cho, S.-W. (2010). Referral, enrollment, and completion in developmental education sequences in community colleges. *Economics of Education Review*, *29*(2), 255–270.

Ball, D. L. (2003). *Mathematical proficiency for all students: Toward a strategic research and development program in mathematics education*. Santa Monica, CA: RAND Mathematics Study Panel.

Barker, W., Bressoud, D., Epp, S., Ganter, S. L., Haver, B., & Pollatsek, H. (2004). *Undergraduate programs and courses in the mathematical sciences: CUPM curriculum guide 2004*. Berkeley, CA: Mathematical Association of America.

Bennison, A. (2015). Supporting teachers to embed numeracy across the curriculum: A sociocultural approach. *ZDM*, *47*(4), 561–573. https://doi.org/10.1007/s11858-015-0706-3

Berg, J., Grimm, L. M., Wigmore, D., Cratsley, C. K., Slotnick, R. C., & Taylor, S. (2014). Quality collaborative to assess quantitative reasoning: Adapting the LEAP value rubric and the DQP. *Peer Review*, *16*(3), 17–21.

Blair, R. M. (Ed.). (2006). *Beyond crossroads: Implementing mathematics standards in the first two years of college.* Memphis, TN: American Mathematical Association of Two-Year Colleges.

Bookman, J., Ganter, S. L., & Morgan, R. (2008). Developing assessment methodologies for quantitative literacy: A formative study. *American Mathematical Monthly*, *115*(10), 911–929.

Brakke, D. F. (2003). Addressing societal and workforce needs. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 167–169). Princeton, NJ: National Council on Education and the Disciplines.

Burn, H. E. (2006). *Factors that shape community college mathematics faculty members' reasoning about college algebra reform: A multiple case study* (Doctoral dissertation).

Retrieved from http://gateway.proquest.com/openurl?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&res_dat=xri:pqm&rft_dat=xri:pqdiss:3237913

California Community Colleges Chancellor's Office. (2017). *Chancellor's office portal home*. Retrieved February 20, 2017, from http://www.cccco.edu/

Carnevale, A. P., & Desrochers, D. M. (2003). The democratization of mathematics. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 21–31). Princeton, NJ: National Council on Education and the Disciplines.

Chesky, N. Z. (2013). *STEM(ming) from where? A philosophical analysis of U.S. mathematics education policies* (Doctoral dissertation). Retrieved from https://digitalcommons.montclair.edu/cgi/viewcontent.cgi?article=1026&context=etd

Clyburn, G. M. (2013). Improving on the American dream: Mathematics pathways to student success. *Change*, *45*(5), 15–23. https://doi.org/10.1080/00091383.2013.824346

Cockcroft, W. H. (1982). *Mathematics counts*. London, England: Her Majesty's Stationery Office.

Cohen, D. (Ed.). (1995). *Crossroads in mathematics: Standards for introductory college mathematics before calculus.* Memphis, TN: American Mathematical Association of Two-Year Colleges. Retrieved from http://eric.ed.gov/?id=ED386231

Cohen, P. C. (2001). The emergence of numeracy. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative literacy* (pp. 23–29). Princeton, NJ: National Council on Education and the Disciplines.

Collins, L. (2002). Shared governance in the California community colleges. *Academe*, *88*(4), 36–40.

Committee on the Undergraduate Program in Mathematics. (1969). *A transfer curriculum in mathematics for two-year colleges*. Berkeley, CA: Author. Retrieved from https://eric.ed.gov/contentdelivery/servlet/ERICServlet?accno=ED062150

Crowther, G. (1959). *The Crowther report*. London, England: Her Majesty's Stationery Office.

D'Ambrosio, U. (2003). The role of mathematics in building a democratic society. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 235–238). Princeton, NJ: National Council on Education and the Disciplines.

Daly, A.J. (Ed.). (2010). *Social network theory and educational change*. Cambridge, MA: Harvard Education Press.

De Lange, J. (2003). Mathematics for literacy. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 75–89). Princeton, NJ: National Council on Education and the Disciplines.

Dossey, J. A. (1997). Appendix: Defining and measuring quantitative literacy. In L. A. Steen (Ed.), *Why numbers count: Quantitative literacy for tomorrow's America* (pp. 173–186). New York, NY: College Entrance Examination Board.

Elrod, S. (2014). Quantitative reasoning: The next "Across the Curriculum" movement. *Peer Review*, *16*(3), 4–8.

Ewell, P. T. (2001). Numeracy, mathematics, and general education: An interview with Peter T. Ewell. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative* *literacy* (pp. 37–48). Princeton, NJ: The National Council on Education and the Disciplines.

Gaze, E. (2014). Teaching quantitative reasoning: A better context for algebra. *Numeracy*, *7*(1), 1–5. https://doi.org/10.5038/1936-4660.7.1.1

Gilliland, C. L. (2010). *Mathematics across the community college curriculum: Annual report* (No. 0442439). Memphis, TN: American Mathematical Association of Two-Year Colleges.

Gillman, R. (Ed.). (2006). *Current practices in quantitative literacy*. Washington, DC: Mathematical Association of America.

Gioia, D. A., & Chittipeddi, K. (1991). Sensemaking and sensegiving in strategic change initiation. *Strategic Management Journal*, *12*(6), 433–448. https://doi.org/10.1002/smj.4250120604

Goldberg, M., Traiman, S. L., Molnar, A., & Stevens, J. H. (2001). Why business backs education standards. In D. Ravitch (Ed.), *Brookings papers on education policy* (No. 4, pp. 75–129). Washington, DC: Brookings Institution Press.

Goldrick-Rab, S. (2010). Challenges and opportunities for improving community college student success. *Review of Educational Research*, *80*(3), 437–469. http://doi.org/10.3102/0034654310370163

Goodman, M., Finnegan, R., Mohadjer, L., Krenzke, T., & Hogan, J. (2013). *Literacy, numeracy, and problem solving in technology-rich environments among U.S. adults: Results from the Program for the International Assessment of Adult Competencies 2012: First look* (NCES 2014-008). Washington, DC: National Center for Education Statistics.

Gordon, S. P. (2006). Where do we go from here? Creating a national initiative to refocus the courses below calculus. In F. S. Gordon & S. P. Gordon (Eds.), *MAA Notes* (Vol. 69, pp. 274–282). Washington, DC: Mathematical Association of America.

Gordon, S. P. (2008). What's wrong with college algebra? *Primus*, *18*(6), 516–541.

Grawe, N. D. (2011). Beyond math skills: Measuring quantitative reasoning in context. *New Directions for Institutional Research*, *2011*(149), 41–52. https://doi.org/10.1002/ir.379

Grawe, N. D. (2013). Does completion of quantitative courses predict better quantitative reasoning-in-writing proficiency? *Numeracy*, *6*(2), 1–18. https://doi.org/10.5038/1936-4660.6.2.11

Greer, B. (2008). Algebra for all? *Montana Mathematics Enthusiast*, *5*(2/3), 423–428.

Hacker, A. (2016). *The math myth*. New York, NY: The New Press.

Hartzler, R. (2005). *Mathematics across the curriculum project final report* (No. 0088149).

Hartzler, R., & Leoni, D. (2006). Mathematics across the curriculum. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 69–74). Washington, DC: Mathematical Association of America.

Herriott, S. R., & Dunbar, S. R. (2009). Who takes college algebra? *Primus*, *19*(1), 74–87.

Hillyard, C. (2012). Comparative study of the numeracy education and writing across the curriculum movements: Ideas for future growth. *Numeracy*, *5*(2), 1–21.

Hillyard, C., Korey, J., Leoni, D., & Hartzler, R. (2010). Math across the community college curriculum (MAC3): A successful path to quantitative literacy. *MathAMATYC Educator*, *1*(2), 4–9.

Howell, C. D. (1997). An assessment of the implementation of shared governance provisions of AB 1725 (1988) at selected California community colleges. *Community College Journal of Research and Practice*, *21*(7), 637–649.

Hubert, D. A., & Lewis, K. J. (2014). A framework for general education assessment: Assessing information literacy and quantitative literacy with eportfolios. *International Journal of EPortfolio*, *4*(1), 61–71.

Hughes-Halett, D. (2001). Achieving numeracy: The challenge of implementation. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative literacy* (pp. 93–98). Princeton, NJ: The National Council on Education and the Disciplines.

Jorgensen, M. (2014). *Barriers to curricular change in general education mathematics at a large public institution* (Doctoral dissertation). Retrieved from https://digitalcommons.usu.edu/etd/3698/

Kennedy, D. (2001). The emperor's vanishing clothes. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative literacy* (pp. 55–59). Princeton, NJ: National Council on Education and the Disciplines.

Kezar, A. (2012). Bottom-up/top-down leadership: Contradiction or hidden phenomenon. *Journal of Higher Education*, *83*(5), 725–760. https://doi.org/10.1353/jhe.2012.0030

Kezar, A. (2013). Understanding sensemaking/sensegiving in transformational change processes from the bottom up. *Higher Education*, *65*(6), 761–780.

Kezar, A., & Eckel, P. (2002a). Examining the institutional transformation process: The importance of sensemaking, interrelated strategies, and balance. *Research in Higher Education*, *43*(3), 295–328.

Kezar, A., & Eckel, P. D. (2002b). The effect of institutional culture on change strategies in higher education: Universal principles or culturally responsive concepts? *Journal of Higher Education*, *73*(4), 435–460.

Kezar, A., & Lester, J. (2011). *Enhancing campus capacity for leadership: An examination of grassroots leaders in higher education*. Stanford, CA: Stanford University Press.

Kim, U., & Stabley, A. (2010). The art of math. *MathAMATYC Educator*, *1*(2), 16–21.

Kirsch, I. S., Jungeblut, A., Jenkins, L., & Kolstad, A. (1993). *Adult literacy in America: A first look at the results of the National Adult Literacy Survey* (NCES 93275). Washington, DC: U.S. Department of Education.

Korey, J. (2008). *Mathematics across the community college curriculum: Student survey results 2005–2008*. Retrieved from http://www.mac3.matyc.org/survey_report%2011_08.pdf

Korey, J. (2010). MAC3 evaluation: Monitoring process, documenting outcomes. *MathAMATYC Educator*, *1*(2), 62–68.

Korey, J., & Hillyard, C. (Eds.). (2010). MathAMATYC Educator [Special issue]. *Mathematics Across the Community College Curriculum (MAC3)*, *1*(2).

Leoni, D., & Hartzler, R. (2010). Recipe for faculty development. *MathAMATYC Educator*, *1*(2), 56–60.

Lott, J. W. (2003). Grounding mathematics in quantitative literacy. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 175–177). Princeton, NJ: National Council on Education and the Disciplines.

Madison, B. L. (2012). If only math majors could write… *Numeracy, 5*(1), 1–12. https://doi.org/10.5038/1936-4660.5.1.6Madison, B. L., & Steen, L. A. (Eds.). (2003).

Quantitative literacy: Why numeracy matters for schools and colleges. Princeton, NJ: National Council on Education and the Disciplines.

Madison, B. L., & Steen, L. A. (2007). Evolution of numeracy and the national numeracy network. *Numeracy*, *1*(1). http://dx.doi.org/10.5038/1936-4660.1.1.2

Madison, B. L., & Steen, L. A. (2009). Confronting challenges, overcoming obstacles: A conversation about quantitative literacy. *Numeracy*, *2*(1). http://dx.doi.org/10.5038/1936-4660.2.1.2

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

National Council of Teachers of Mathematics. (1980). *An agenda for action: Recommendations for school mathematics of the 1980s*. Reston, VA: Author.

National Leadership Council for Liberal Education and America's Promise. (2007). *College learning for the new global century*. Washington, DC: Association of American Colleges and Universities. Retrieved from http://www.voced.edu.au/content/ngv:54115

Niss, M. (2003). Quantitative literacy and mathematical competencies. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 215–220). Princeton, NJ: National Council on Education and the Disciplines.

Organisation for Economic Co-operation and Development & Statistics Canada. (1995). *Literacy, economy, and society: Results of the first international adult literacy survey.* Paris: OECD Publications and Information Center.

Orrill, R. (2001). Preface: Mathematics, numeracy, and democracy. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative literacy* (pp. xiii–xx). Princeton, NJ: National Council on Education and the Disciplines.

Packer, A. (2003). What mathematics should "everyone" know and be able to do? In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 33–42). Princeton, N.J.: National Council on Education and the Disciplines.

Paulos, J. A. (1988). *Innumeracy: Mathematical illiteracy and its consequences*. New York: Hill and Wang.

Prichard, G. R. (1995). The NCTM standards and community colleges: Opportunities and challenges. *Community College Review*, *23*(1), 23–32. https://doi.org/10.1177/009155219502300104

Proctor, A. R. (2011). *The relationship between the secondary mathematics curriculum, college persistence, and success at an urban community college* (Doctoral dissertation). Retrieved from http://digitalcommons.fiu.edu/cgi/viewcontent.cgi?article=1582&context=etd

Richardson, R. M., & McCallum, W. G. (2003). The third R in literacy. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 99–106). Princeton, NJ: National Council on Education and the Disciplines.

Rogotzke, K., Zoellner, C., Larson, K., & Fallis, N. (2010). The evolution of a learning community for elementary education majors. *MathAMATYC Educator*, *1*(2), 50–54.

Roohr, K. C., Graf, E. A., & Liu, O. L. (2014). *Assessing quantitative literacy in higher education: An overview of existing research and assessments with recommendations for next-generation assessment* (ETS Research Report No. RR-14-22). Princeton, NJ: Educational Testing Service. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/ets2.12024/pdf

Root, R. (2009). Social justice through quantitative literacy: A course connecting numeracy, engaged citizenship, and a just society. *Science and Math: Equity, Access, and Democracy*, *18*(3), 37–43.

Rosen, L. P. (2001). Quantitative literacy in the workplace: Making it a reality. In L. A. Steen (Ed.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 37–48). Princeton, NJ: National Council on Education and the Disciplines.

Rosen, L. P., Weil, L., & Von Zastrow, C. (2003). Quantitative literacy in the workplace: Making it a reality. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: why numeracy matters for schools and colleges* (pp. 43–52). Princeton, NJ: National Council on Education and the Disciplines.

Saldaña, H. (2009). The coding manual for qualitative researchers. London, England: Sage.

Scherger, N. (2013). The redesign of a quantitative literacy class: Student responses to a lab-based format. *Teaching Mathematics & Its Applications*, *32*(4), 206–213.

Seymour, E. (2002). Tracking the processes of change in U.S. undergraduate education in science, mathematics, engineering, and technology. *Science Education*, *86*(1), 79–105.

Shavelson, R. J. (2008). Reflections on quantitative reasoning: An assessment perspective. In B. L. Madison & L. A. Steen (Eds.), *Calculation vs. context: Quantitative literacy and its implications for teacher education* (pp. 27–44). Washington, DC: Mathematical Association of America.

Small, D. (2006). College algebra: A course in crisis. In N. B. Baxter, F. S. Gordon, S. P. Gordon, & J. Narayan (Eds.), *A fresh start for collegiate mathematics: Rethinking the courses below calculus* (pp. 83–89). Washington, D.C.: Mathematical Association of America.

Sons, L. (1994). *Quantitative reasoning for college graduates: A complement to the standards*. Washington, DC: Mathematical Association of America. Retrieved from http://www.maa.org/programs/faculty-and-departments/curriculum-department-guidelines-recommendations/quantitative-literacy/quantitative-reasoning-college-graduates

St. Clair, R. (2012). The limits of levels: Understanding the International Adult Literacy Surveys (IALS). *International Review of Education*, *58*(6), 759–776.

Steele, B., & Kiliç-Bahi, S. (2008). Quantitative literacy across the curriculum: A case study. *Numeracy*, *1*(2), 3.

Steen, L. A. (n.d.). *CUPM recommendations: The first forty years*. Washington, DC: Mathematical Association of America. Retrieved from http://www.maa.org/programs/faculty-and-departments/curriculum-department-guidelines-recommendations/cupm/first-40-years

Steen, L. A. (1997a). Preface: The new literacy. In L. A. Steen (Ed.), *Why numbers count: Quantitative literacy for tomorrow's America* (pp. xv–xxviii). New York, NY: College Entrance Examination Board.

Steen, L. A. (1997b). *Why numbers count: Quantitative literacy for tomorrow's America*. Retrieved from https://hal.archives-ouvertes.fr/hal-00699761/

Steen, L. A. (1999). Numeracy: The new literacy for a data-drenched society. *Educational Leadership*, *57*(2), 8–13.

Steen, L. A. (2001a). *Mathematics and democracy: The case for quantitative literacy*. Princeton, NJ: National Council on Education and the Disciplines.

Steen, L. A. (2001b). The case for quantitative literacy. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative literacy* (pp. 1–22). Princeton, NJ: The National Council on Education and the Disciplines.

Steen, L. A. (2003). Data, shapes, symbols: Achieving balance in school mathematics. In B. L. Madison & L. A. Steen (Eds.), *Quantitative literacy: Why numeracy matters for schools and colleges* (pp. 53–74). Princeton, NJ: National Council on Education and the Disciplines.

Steen, L. A. (Ed.). (2004). *Achieving quantitative literacy: An urgent challenge for higher education*. Washington, DC: Mathematical Association of America.

Todd, V., & Wagaman, J. (2015). Implementing quantitative literacy at Southwestern Community College, North Carolina. *Numeracy*, *8*(2), 9.

Usiskin, Z. (2001). Quantitative literacy for the next generation. In L. A. Steen (Ed.), *Mathematics and democracy: The case for quantitative literacy* (pp. 79–86). Princeton, NJ: National Council on Education and the Disciplines.

Vacher, H. L., & Lardner, E. (2010). Spreadsheets across the curriculum, 1: The idea and the resource. *Numeracy, 3*(2), 1–22.

Vacher, H. L., & Wallace, D. (2013). The scope of *Numeracy* after five years. *Numeracy*, *6*(1), 1–13. https://doi.org/10.5038/1936-4660.6.1.1

Van Peursem, D., Keller, C., Pietrzak, D., Wagner, C., & Bennett, C. (2012). A comparison of performance and attitudes between students enrolled in college algebra vs. quantitative literacy. *Mathematics & Computer Education*, *46*(2), 107–118.

Ward, R. M., Schneider, M. C., & Kiper, J. D. (2011). Development of an assessment of quantitative literacy for Miami University. *Numeracy*, *4*(2), 1–19.

Weick, K. E. (1976). Educational organizations as loosely coupled systems. *Administrative Science Quarterly*, *21*(1), 1–19.

Williams, M. (2016). *A reformed college algebra course: Understanding instructors' and students' beliefs about teaching and learning mathematics* (Doctoral dissertation). Retrieved from https://digitalcommons.unl.edu/teachlearnstudent/66/

Wismath, S., & Worrall, A. (2015). Improving university students' perception of mathematics and mathematics ability. *Numeracy*, *8*(1). http://dx.doi.org/10.5038/1936-4660.8.1.9

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage.