STUDENT AND TEACHER: A MODEL AND CRITERIA TO UNDERSTAND AND EVALUATE AUTHORITY ISSUES IN THE TECHNOLOGY CLASSROOM

DISSERTATION

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By

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ABSTRACT

Electronic computing technologies have been part of an immense change in the ways that groups communicate and represent knowledge. As interaction changes, so too do the rules within which interactions occur. Education, the arena of much rhetoric regarding technology and change has welcomed the computing hardware into schools, but in many respects seems to have made few changes to educational processes in response to the changes surrounding new technologies. Assessment, pedagogy, and the status of knowledge and its creation/exchange have moved little with changes in technology. In this document, the adequacy of traditional models of authority are called into question in light of the growing presence of technology (especially computers) in the classroom. A new model of characterization based on the work of John Dewey, Michel Foucault, Michael Apple, and others is developed to better suit the ways that electronic technologies have redistributed knowledge, and therefore power. A set of probative questions (or criteria) is then elaborated as a guide to inquiry into authority issues in the classroom. Data from two computer-based, university-level calculus courses are used to
demonstrate the need for a new model of authority, to test the appropriateness of the new model, and to exemplify the utility of the inquiry questions. A vision for rethinking authority in mathematics classrooms is offered, suggesting that complexity theories and the principles of collective intelligence offer one way for developing new approaches to mathematics education that reflect new ways of thinking about authority.
DEDICATION

To Jenny.

Siempre fuiste la razon de mi existir
Adorate para mi fue' religion...
-Carlos Almara'n, "Historia de un amor"
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In the recent round of mathematics standards, the National Council of Teachers of Mathematics' (NCTM) *Principles and Standards* (2000) lists the “Technology Principle” as one of only six principles used to frame decisions about what constitutes good mathematics education. Within current educational discourse, technology has become as important as the other five principles cited: equity, curriculum, teaching, learning, and assessment. Is technology really as important to educational discourse as learning or teaching? This rise in the perceived importance of technology issues in mathematics education correlates to a rise in the number of computers and calculators in the classroom and in student homes and residence halls in the past two decades. The ratio of computational power per dollar has risen steeply over the past few decades, meaning that the mathematics that students are engaging in, the ways they are engaging in that mathematics, and the ways that mathematics is being practiced have all changed significantly.

The popular construction of “(educational) technology” as synonymous with “calculator” and/or “computer” is limiting in many ways. Indeed, calculators and
computers can not be abstracted from a much broader set of technologies that accompany them. For instance, mathematics' use of graphs as devices for seeing relationships and trends is a technology that is closely tied to what is deemed valuable about computers and calculators. Furthermore, WebQuests are becoming a popular format for Internet-based lessons in which students use the World Wide Web (WWW) to seek answers to a pre-defined set of questions. This exemplifies the ways in which computers (and calculators) are changing pedagogy and communication within the classroom. Pedagogy, curriculum, the organization of the physical classroom, all could be thought of as important technologies that respond in meaningful ways to each other and to changes such as the growing presence of electronic technologies within the classroom. It is difficult to isolate what counts as “technology” because of the interrelatedness and complexity of the spaces in which technologies reside.

Nevertheless, change is taking place within classrooms and popular political and educational discourse. While these changes are easily sensed, educators still have the task of understanding the nature of these changes. Old frameworks for understanding the relationship between teachers and students, for example may be inadequate or unproductive in the light of technological changes. Without accurate frameworks or models, it is difficult to predict or understand the effects of these changes. Even classrooms without computers or calculators must still feel the effects of changes within technology. Current technologies have reshaped the ways in which we think with, about, and through information. These effects have been incorporated in movies such as The Matrix (1999), in which the world of the Matrix may be experienced as a video game.
Similarly, many newspapers have shaped layout of the printed word in ways that reflect the hyperlinking and frames structure of Websites. In brief, the impact of electronic technologies (and therefore other intertwined technologies) on culture, society, economics, and politics has been comprehensive.

1.1 The Problem

Educational research must re-examine the frameworks used to understand the component parts and processes of education. Beginning with the often taken-for-granted assumptions behind current frameworks, researchers must chart a course for examining current frameworks, testing for their adequacy, and, when necessary, formulating alternate frameworks and models to be used in education. This project is guided by the question: “In what ways are our conceptual frameworks (in)adequate, and how might we modify them to attend to changes in technology in the mathematics classroom?” In particular, this project is an examination of how frameworks for understanding the student-teacher relationship, most notably that of authority, change in the face of technological changes.

1.2 Why it is Important

The relationship between theory and practice, as Davis, et al. reminds us is one of an unbreakable interconnection: “All practice is theorized (that is, all actions derive from particular ways, explicit and tacit, of seeing the world) and that all theory influences practice (that is, how we think influences how we act, although not always in obvious or
conscious ways)” (2000, p. xi). The frameworks explored here are bound to practice, and any instabilities they possess are reflected in shaky practices. If our models and modes of thinking about the ways that students and teachers relate, the ways that we marshal active and collaborative learning methods, the ways we understand gender, and the ways that we think about models for mathematical learning are not tuned to the current state of technological change, then our educational practices will suffer.

Current research journals in math education print a large amount of research on “things” typically associated with “practice”: “methods,” “representations,” and “curriculum.” However, while many articles may explore a teacher, few explore “teaching.” Similarly, while many articles differentiate according to gender, few explore what “gender” means in the context of mathematics. In other words, there are unquestioned assumptions embedded deep within the theoretical frameworks and models used in most mathematics education research. The heart of the taken-for-granted matter comprises what we think of when referring to “teaching” and “learning,” for example. So while some progress has been made in understanding how technology can be implemented in the classroom, more work needs to be done in terms of understanding what is meant by “implement” and who it is that is doing the “implementing.”

The core assumptions of the frameworks are targeted as part of an examination of that which is taken-for-granted. This is an important step prior to the reconstruction of frameworks that are more useful for understanding educational practices in today’s technology classrooms (embedded as they are within today’s technological communities and societies). The goal is not to create theories that are harmonious with a reality, but to
find resonance between our ways of thinking about and constructing practice, and the practices themselves. This is the sort of *pragmatism* of which Frank Macke speaks when he describes “a discourse on the consequences of thinking,” (Macke, 1995, p. 158) that emphasizes “results of action” (Cherryholmes, 1999). Our goal, then, is to reflect on practice and to practice reflexively so that deep, critical inquiry may better construct more productive ways of thinking about mathematics education.

1.3 Ways to Address the Problem

Education is a social institution; a set of beliefs and practices instituted by a community. Educational research must therefore be a conversation among members of the communities in which education is practiced. Achieving the goal stated in this paper, to analyze and reconstruct frames for understanding, requires a profound conversation on a community-wide scale. One goal of this paper is to inspire conversation by offering insightful analyses and starting points for making our conceptual models more useful to the members of the education community. Some within the community may not see a problem at all, while some may see technology as the problem. These perspectives must be included in the conversation as part of an ethics of inclusion and a belief in democratic education. For now, I encourage the reader to reflect on a question of values posed by Damarin (1994, p. 57) that encourages us to think about the subtle ways that technology has influenced our lives: “Would you give up your laptop?” Is the question answerable? Would it be answerable if “laptop” was taken here to mean the “comfy” place for children to sit to listen to stories?
The point of this exercise, of course, is to suggest that regardless of the extent to which someone agrees that technology is infused in society and culture, that it nevertheless has *some* effect. This is common ground upon which to begin a conversation about the ways in which we think about or frame understanding of various aspects of education. Having begun the journey, we need an understanding of what directions or guides are available to influence the path we take. There are two answers. First, since ours is a journey through familiar ideas, previous research serves as an old map – a diary of previous explorers. Chapter two will examine relevant perspectives and research. Even though the ideas are familiar, the landscape has changed and we are therefore explorers in new territories. It has been said that you can not step in the same river twice, and even as we explore we must be aware of how our own presence changes the space around us and therefore our experiences of that space. Chapter three will explore the various tools used to explore and to see from the maps to the landscape. It will furthermore discuss the limitations and ethics of using our research methods. Though this is not primarily an empirical study, data are collected from a exemplary site that is rich in technology use and will be a good testing ground for adding meaning to and testing the usefulness of our modified framework.
1.4 Implications of Looking at the Problem

It is important to consider the consequences of exploring the research problem. The abuses and unintended maladies of research are familiar. While oversight boards such as Human Subjects Review Committees (HSRCs) are an important safeguard, the principal investigator is ultimately responsible for the data and, to some extent, for the consequences of that research.

The “problem” put forth in this project is a problem that I am intentionally constructing. The consequences of inaction, or not seeking to rethink existing frameworks for understanding are easily seen. The status quo doesn't exist anymore; technology is a social impulse that gives momentum to change from without and within communities. The ground is moving under our feet and, should we fail to reconsider our ways of thinking about fundamental concepts and processes of education like teaching and learning, then we risk one day waking up in a future we no longer recognize and cannot begin to comprehend. The risks of inaction, of not approaching the problem, are therefore clear and suggest the importance of the study.

Dissertation research is a juried conversation, a process involving an intentional oversight of details meant to protect the participants of the research (of which I include the researcher) and to support learning. As such, it is, minimally, a fairly contained experience involving the attempts of a student to address a problem and to graduate. Yet, the dissertation often spawns careers and articles, thus widening the scope and exposure of the ideas to others, while at the same time exposing the participants to greater risks. Every effort has been taken to obscure the identities of the on-site participants in
reporting and analyzing the data, so the risks to the participants should be minimal. The possibilities for starting or shaping debate over the uses of technology and the influence of technology on aspects of education are potentially very great. It is my hope that this dissertation creates a space for debate and inquiry into issues of teaching and learning mathematics. I further hope that it spawns further explorations of the once-charted-but-now-forgotten-territory of assumptions that shape mathematics education. Many of the ideas and concepts contained in the dissertation come from other disciplines. One goal for this dissertation is that it establishes a discourse-rapport between various fields, such as cultural studies and mathematics education, that have sometimes been quite distant from each other.

1.5 The Structure of the Dissertation

There is a natural ordering suggested by the problem given its focus on four separate frameworks. The most natural organization follows:

- Chapter one: An introduction that describes and motivates the problem by establishing some context. This describes the structure of the analysis chapter, that is of the form: 1) examine existing frameworks and discuss any inadequacies in the light of technology; 2) suggest a new model or framework for understanding the topic and furnish criteria for applying the framework to analyze the data; 3) an empirical application of the framework used as an example of how the model structures meaning and offers productive alternatives to existing models (where applicable).
• Chapter two: A review of relevant literature that sets the stage for the (re)construction of a framework for authority. Part of the analysis (chapter four) will involve a conversation between existing research perspectives so chapter two will serve as a brief review of literature that should give the reader enough background to feel comfortable with the use of literature in chapter four.

• Chapter three: A description of methods/methodologies used in collecting the empirical data. This includes a methodological discussion centering on grounded theory research (Strauss & Corbin, 1994) and critical poststructural concerns regarding truth and reality. Ethics, validity, a description of the site, and the mechanics of methods are also included here.

• Chapter four: “Student and teacher: A model and criteria for understanding authority in the technology classroom.” This chapter examines the relationship between students and teachers based on the premise that the distinction between “student” and “teacher” is rhetorical and based on an outdated concept of “authority.” A new model for characterizing authority is offered and criteria are suggested for use in analyzing the effects of technology in terms of the student-teacher dynamic. The distinction between “student” and “teacher” is softened, leading to a more democratic and potentially more productive vision for classroom exchange. Major theoretical influences include John Dewey, Michel Foucault, Thomas Popkewitz, Michael Apple, Cleo Cherryholmes, and Valerie Walkerdine.

• Chapter five: Implications and Conclusion.
New visions for authority have enormous implications for educators. This includes the need to re-evaluate existing classroom management strategies, ways of thinking about knowledge (including who owns it), learning (who has the right to learn it), and institutional organization.

1.6 Research Questions

The central question explored in this dissertation is “(How) should we (re)conceive of the student-teacher dynamic and issues of authority in the classroom?” There are several sub-questions that spring from this, including:

- How can a computer calculus classroom shed light on the issue?
- Is the material concept of authority useful for understanding and structuring educational environments?
- How is technology implicated?
- What characterizes a useful model of authority and what are the criteria upon which we can examine classroom technologies to understand their implication in issues of authority?
- In what ways is mathematics authorless yet self-authorizing? What are the implications of a new model of authority on the subject and practice of mathematics?
CHAPTER 2
THEORETICAL FRAMEWORKS AND CONTEXTUAL MOTIVATION

2.1 Introduction

The first words of Marshall McLuhan's and Quentin Fiore's 1967 *The Medium is the Massage* start, “The medium, or process of our time – electronic technology – is reshaping and restructuring patterns of social interdependence and every aspect of our personal life. It is forcing us to reconsider and re-evaluate practically every thought, every action, and every institution formerly taken for granted” (pages unnumbered). In 1967, there were far fewer computers than in 2002. While we could never guess whether or not McLuhan and Fiore predicted the computer saturation present in today's classrooms and homes and the proliferation of relatively inexpensive yet powerful computers, they clearly understood then that electronic technologies change with the social fabric in ways that make older ways of understanding less useful in the world. Our conceptual frameworks and our assumptions, the “taken for granted” aspects of our life, need constant updating and critical reflection.
In an effort to contribute to conceptual reconstruction, I “reconsider,” and “re-evaluate” a way of seeing the world particular to education. Educational praxis unquestioningly differentiates the roles of “student” and “teacher” according to a heavily lopsided placement of authority within the teacher over the student. The prevalence of electronic technologies and new communication media forces us to reconsider this construction. This chapter attempts to briefly situate the problem in popular and professional context. There is a constant interplay within the following sections of what is said (usually in written form), what is done (in terms of action and policy), and what is not said and done (the taken-for-granted). This is just a brief overview, as the particulars are explored in more detail in the analysis chapters that follow. First, however, an exploration of what is meant by technology is in order.

2.2 What is Technology?

There is a widespread belief that the term “technology” is equivalent to “tool.” Furthermore, when people think of “technology” in everyday use, it almost always concerns electronic technologies such as computers, calculators, and medical apparati. Though a tool is a technology, the term “technology” has a social component – it embodies more than just “a utility.”

Technologies are socially situated; their influences are expressed socially according to various models. The most prominent of these models, and the model that seems to guide most educational practice is that of technological determinism, that “prescribes a one-way relationship between machines (technology) and people (society),
in which technologies change, and that change impacts on people. In this formulation, technology and society are kept separate, even held in opposition to one another: technology causes social change (Bell, p. 66).” This viewpoint is seen in the NCTM's (2000) Technology Principle that begins, “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning (NCTM, 2000).” A change in technology leads to a change in students' experience (learning). Minimally, the Technology Principle enacted models an “add technology and stir” perspective of technology.

Bell (2001) and Bromley (1997) outline other approaches to characterizing and modeling technology. The principal differences among the approaches have their source in the tension between the viewpoint that “technologies are intrinsically biased” and “what matters is how they are used” (Bromley, 1997, p. 52). As Bromley points out, this debate relies on a false distinction between technology and society. Bell and Bromley see the differences according to a variety of cause and effect models. Technological determinism could be modeled by technology-->society. The social construction of technology (SCOT) model reverses the direction of the arrow: society-->technology. A SCOT viewpoint of technology would argue that the automobile looks and acts like it does because it was designed to accommodate people's comfort with the horse and carriage as opposed to a shape designed to better fit the new technology of an internal combustion engine.

More useful models put the model in spin with society-->technology-->society acknowledging the social nature of technology without resorting to technological
determinism on the one hand, or *technological neutralism* (the belief that technologies are bias-free as seen in the line “guns don't kill people, people kill people”) on the other. Such a model demands an approach that allows for the freeplay of socio-technological change.

Bell reminds us that “multiplicity and contingency should guide us: we need *really useful theory*” (Bell, 2001, p. 89). Wise (1997) describes technology as “a socially active hybrid that connects with others and bends space while being at the same time coded by abstract forces” (quoted in Bell, 2001, p. 79). By “space” here, Wise most certainly means the socio-cultural and discursive complex in which human (inter)action occurs. This account of technology is particularly useful given that it includes schooling, blackboards, assessment techniques, pedagogy, computers, and even time. In instances in which the context is unclear, I will attempt to use “electronic technologies” or some variant when talking about computers and calculators and simply “technologies” when the intended meaning is more general.

Part of the search for a “*really useful theory*” (Bell, 2001, p. 89) of technology involves not just what technology *is*, but also how it is coded as a symbol of quality within popular educational discourse (Bromley, 1997, p. 52), how its design and use limit/are limited by issues of access, and how a better understanding of technology in education can serve students and educators. By failing to reconsider the ways that education conceives of technology, by relying on old and overly-simplistic models of technological determinism or technological neutralism, we risk misunderstanding the effects of technology and its impact on issues of assessment and learning. In short, we
risk profound injustices practiced on teachers and students if we fail in finding a useful theory of technology that is itself responsive to change. Popkewitz and Shutkin note that the introduction of computer technology involves more than material changes in classrooms. It also entails introducing systems of ideas for seeing, thinking, acting, and talking about schooling. This deep structure to change is implicit in much of the curriculum designed for computer use in schooling, drawing attention to the fact that introducing a technology or designing a curriculum is more than adding a curriculum strategy to existing classroom practices. The potential of the curriculum intervention is to alter the categories, distinctions, and differentiations for interpreting and effecting practice (1993, p. 24).

Educational research should instead follow the path suggested by Andrew Roth (2000) involving a hacker-like pursuit of the meanings and practices of technology, critically confronting from a position of intimate knowledge of technology.

Part of understanding technology is knowing how access to those technologies is structured. Too often the term “access” in educational discourse refers to “computers in the classroom” - the physical access to a machine. There are, unfortunately, many instances in which the computer is materially present but still inaccessible. The term “access” must include a sense of “usability,” so that a computer would be considered inaccessible to a student if: the teacher's lack of experiences made for pedagogical choices not to use the computer in the classroom, the software was not available or was too difficult to use by students, the hardware was inadequate to support the software being used, network access was limited or non-existent, social dynamics meant that certain individuals or groups maintained an exclusive use or control over the computers (for instance if in a group of students one or two constantly are allowed to control the keyboard and mouse), or if a student's physical impairments limited their use of the computer. Access then is a property not of the material presence of the computer, but a
property of the machine, the social group that uses the computer, pedagogy, curriculum, and teacher/administrative support. As Mark Warschauer puts it, access is “not so much the availability of the computing device or the Internet line, but rather people's ability to make use of that device and line to engage in meaningful social practices” (Reconceptualizing the Digital Divide, p. 13).

The existence of literature that demonstrates alternatives to technological determinism/neutralism, to narrow definitions of technology and access, and to believing that technology is a non-issue in education, offers support to the current project. Technology is inextricable from society and changes can only be understood as simultaneous socio-technological changes. Technology is more than a tool, it is a symbol and a process for connecting people and, like celestial bodies, bends the space it inhabits. Technology access is a principle that entails realizing the extent to which people are able to make use of the technology as they engage in meaningful activities. This project adopts Ross' hacker-like approach to technology, avoiding dualisms so often found in discussions about technology: Luddite/technophile, human/machine, approaching technology cautiously, energetically, and critically. These concepts of technology will be used throughout the dissertation.

2.3 Authority as a model of the Student-Teacher Dynamic

Traditional approaches of student-teacher relationships are difficult to locate within literature. So taken for granted is the notion of teacher as supreme authority that it seems to need no explicit study or justification within literature. Still, the effects of the
teacher as authoritarian model can be observed within literature on maintaining discipline within the classroom, curriculum, and pedagogy. On a personal note, I was told early in my own teaching career at both the high school and college levels to “be a 'hardass' the first few weeks if you ever expect to maintain control.” The culture of teaching and schooling promotes an atmosphere of control and discipline that places the teacher at the center of classroom control. Even within a reform rhetoric of “social construction” as a model for learning, students may converse with peers to “construct” knowledge, yet the teacher almost always has a sense of the “right” answer that the students are to arrive at, severely limiting the scope of the “social” in “social constructivism.”

Within educational literature, however, there are promising directions for reshaping a model of authority that recognizes the highly distributed nature of knowledge. Beginning as early as Dewey, some scholars have hinted at the ways in which authority could be reconfigured to make schools and learning more democratic processes. There are three bodies of research literature that guide the formation of a better model for authority. First, Deweyan educational philosophy stresses democratic values in education. Second, the Foucaultian tradition of understanding power as a productive force closely tied to knowledge (a tradition from which Popkewitz, Cherryholmes, and Walkerdine come). And third, the political educational philosophy of Michael Apple dealing with the ways that social valuations of knowledge participate in “official knowledge” and “high status knowledge” (HSK). These three areas, handled individually in the subsequent paragraphs, will contribute to a model of authority and student-teacher dynamics that is more in tune with the technology-enriched classroom.
They will move us from a sense of authority too closely tied to “despotism” toward a recognition of the “author” as the root of “authority.” It highlights agency and hope, a nomadic progressivism driven by the belief that things can only get better by recognizing individuals within societies as sites and stimuli of change.

Furthermore, there is a need to begin to see pedagogy and assessment as expressions of authority. Pedagogy is a “sanctioned” way of approaching learning, and, as McLuhan and Fiore (1967) remind us, the medium is often the message. When mathematics is presented as something that people do together versus independently, students are inclined to sanction group learning as the “right” way to do mathematics. Similarly, assessment is an expression of authority, as in the case of the “high stakes” testing occurring in nearly all of the nation's classrooms. The tests communicate not only an officially sanctioned version of the content that counts as legitimate knowledge, but also the officially sanctioned means for measuring that knowledge. Many students who have been forced to take these tests in English despite not speaking the language receive the message that the only knowledge that counts is that which is measured in the English language. Changing our model of authority may work to promote justice and equity by recognizing the ways that pedagogy and assessment are expressions of authority and therefore sites for contestation and negotiation.
2.3.1 Dewey

Dewey, in *Democracy and Education* (1916) and also *Authority and Freedom* (1936), emphasizes the highly political and economic nature of schooling – the ways in which power and authority are constructed to manage the (re)distribution of resources to shape students’ loci within society, culture, and class. Dewey observed a social tension between authority and individual freedom. He argues that these should not be constructed as opposites, but that they are interconnected and can complement each other in the context of education. This is important not only because it builds a much-needed rhetorical middle road, but also because it reaffirms that authority is intricately woven into many other political concepts like individual freedom.

Issues of authority were extremely important to John Dewey and his development of a political philosophy of education. For Dewey, issues of authority surfaced in their relationship to individual freedom. During the early part of the twentieth century, such issues were paramount as dominant educational and philosophical discourse was saturated with talk of “regimentation,” “socialism,” and “democracy.” Dewey witnessed the rhetorical separation of authority and individual freedom into two disjoint spheres. Given the importance of authority to education, as well as the mission to foster individuality (which, according to Boisvert (1998), Dewey distinguished from “individualism”), the dualization of these two concepts put education in an untenable position. Educational reform fared worse yet given the association of the “stability-change” duality with that of “authority-individual freedom,” since “stability” is often seen as beneficial and “change” as unsettling.
Hence Dewey's treatment of authority is one which recognizes the value of authority to education (as mentioned above), but simultaneously the need for individual freedom as a criterion for a democratic education. For Dewey, “authority stands for stability of social organization by a means of which direction and support are given to individuals; while individual freedom stands for the forces by which change is intentionally brought about.” (1936, p. 603) What Dewey sought was “the intimate and organic union of the two things: of authority and freedom, of stability and change” (p. 603).

The history of schooling in the late nineteenth century was one of rigid authority and discipline, of McGuffey's readers and monotonous repetition. Dewey was sympathetic to his contemporaries' concerns with getting rid of oppressive authority in the schools, yet he was also cautious to not abandon the importance of authority in preventing confusion and chaos (on both macro- and micro-scales). He was a proponent of individual freedom as a core component of a social, moral, and personal education yet recognized that unchecked, individual freedom becomes “license” (p. 603) which I take to mean an anarchical dispensation of any social norms or rules.

Furthermore, Dewey recognized the importance of power, and the tie between power, authority, and stability. Historically, he viewed education as “a struggle between groups and classes of individuals – between those who were enjoying the advantages that spring from possession of power to which authoritative right accrues, and individuals who found themselves excluded from the powers and enjoyments to which they felt...
themselves entitled” (p. 603). Those in power desire the stabilizing effects of authority so as to maintain existing power relations in their own self interest.

Recognizing that “the pathos of the collective life of mankind on this planet is its exhibition of the dire human need for some authority; while its ever mounting tragedy is due to the fact that the need has been repeatedly betrayed by the very institutions that claimed to satisfy it” (p. 603). Dewey negotiated a harmony between authority and freedom. Dewey “need[ed] an authority that, unlike the older forms in which it operated, [was] capable of directing and utilizing change” (p. 603). Furthermore, he needed a “kind of individual freedom that is general and shared and that has the backing and guidance of socially organized authoritative control” (p. 603).

Striking such a balance is achieved through the “utilization of organized intelligence” (p. 603) as modeled by science. What he termed a “collective intelligence” replaces a centralized authority by distributing authority over a wide population of educated citizens who conform to the institutional authority of science and reason. Science, for Dewey, exemplified the “organic, effective union” (p. 603) of authority and freedom. It upheld individual values of innovation, enterprise, and initiative while conforming to social needs for the stabilizing effects of authority which “issues from and is based upon collective activity, cooperatively organized” (p. 603).
Echoes of Dewey's “collective activity/intelligence” may be seen in current models of “distributed intelligence” and the organization of the World Wide Web into “nodes,” operating according to formalized rules and informal convention to compose an organic blending of individuality and authority. This will be further exploited in later sections.

2.3.2 Power

Foucault (1979, 1980) argues that “power” doesn't function in society like a commodity or materiality – something that exists as a limited resource and is distributed in such a way that power is “possessed” in disproportionate quantities by different social groups. Instead, he argues for a “productive” that is a property created, maintained, and shared by groups of people only so long as those groups remain intact. For instance, students and teachers exist in a negotiated complex of power whereby learning operates according to a negotiation of the teacher's obligation to serve as facilitator and judge and the students' need to be helped and to be “accredited.” When the course is over, the power that helped to define that relationship dissolves. Popkewitz and others mentioned above pick up this sense of power in their work on issues of schooling. For the purposes of this project it is useful in that it moves the discussion beyond the ratio of

\[ \text{student:teacher}=\text{powerless:powerful}. \]

Power is \textit{enabling} rather than disabling.
Furthermore, Foucault recognizes a sense of power (and therefore knowledge and authority) that is deeply embedded in other social processes, either covertly or overtly – a characteristic that is of the utmost importance in understanding issues of knowledge and authority in the technology classroom.

For Michel Foucault and his proteges, “authority” is inseparable from “power,” “discourse,” and institutionalized “regimes of truth.” But the sense of power used by “post-structural” philosophers such as Foucault (1977), Popkewitz(2000), Cherryholmes(1988), and Walkerdine(1988), is different from that used by Dewey. To Dewey “power” was a term that needed little if any definition. Deweyan power is a power in a materialist sense – there is a limited amount of power in any situation and often one group has more power than another within that situation. Appelbaum (1995) describes this as an “economics of power” in which power is viewed as an “asset” like money or stock. This sense of power is a “repressive” sense of power since those with power are “powerful” whereas those with little or no power are “powerless,” having limited abilities (individually or socially) for agency.

Foucault began with the doubt in any sort of absolute truth. He furthermore recognized that the adage “knowledge is power” combined with a doubt in absolute truth leads to the conclusion that “knowledge” was a construct of groups of people at specific (local) times and locations. “Authority,” then, could be thought of similarly as an exercise of power-knowledge by a group of people. This sense of “power” is fundamentally different from the materialist version mentioned above. This is what Appelbaum (1995) would term a “physics of power” because it is not limited within any
situation, but rather is a property held between two or more groups, just as gravity is a force that exists between two (or more) objects. This is not a repressive sense of power because power is a shared construct, generated by the coming together of multiple groups.

When groups come together in an exercise of power, authority is concurrently manufactured as part of “regimes of truth” or localized agreements about what counts for knowledge, for truth, and therefore authority. So, like power, authority is a shared property, an exercise in consent and the institutionalization of rules that define norms, truths, and conventions.

For education, this sense of authority and power confronts more traditional materialist views of authority and power and suggests that students, teachers, and other participants within education share in the authorization, regimentation, and institutionalization of knowledge, power, and authority, even if those participants aren't cognizant of those roles.

Furthermore, this sense of authority as a construct shared among groups is consistent with Dewey's desire for an individual freedom that exists according to social consensus. In a strict Foucaultian tradition, individual freedom doesn't exist. Rather, individuals are viewed as (sometimes unwitting) participants within a complex of social forces that dilute any sort of “pure” individual action – a person's actions are always already influenced by social and political pressures.

For Dewey, authority and power are overt characteristics of institutions. For Foucault, power and authority become more and more covert as regimes of truth operate
long enough to obscure the geneses of authority and power. Citizens and students adopt a “governmentality” in which “freedom” is a covert construct of a regulating “authority.” Cleo Cherryholmes (1988) notes that as power becomes invisible, “authority” becomes a discursive construct. Authority shifts from being a property of a select group of people (the authorities), to being a property of a system of rules, conventions, actions and utterances (a “discourse”) that exists through the explicit or implicit consent of participants within that discourse. (Here “discourse” is used to mean something more than just “speech acts” or “text.” Discourse is a collection of actions, rules, institutions, participants, texts, utterances, habits, and actions that are bound together by an implicit social charter. For example, post-secondary school reform is a discourse and the rules, beliefs, researchers, students, instructors, politicians, textbooks, buildings, all contribute to the operation of the discourse. The charter of such a discourse involves an expressed commitment to change within post-secondary education.)

When authority becomes invisible, the consent of the participants is no longer an active consent to the principles upon which the authority was established. Rather, the participants' performance within the institutions is a tacit consent that perpetuates the sort of stability that Dewey associated with authority. Valerie Walkerdine (1988), in looking at mathematics education in the United Kingdom, saw the ways in which the discourse of “Reason” had been granted a no-longer-questioned authority and power of control. Walkerdine would no doubt take issue with Dewey's contention that the scientific method represents an organic fusion of individual freedom and authority. For Walkerdine, science and the scientific method are parts of a discourse that give reason an
unquestioned authority that leads to an invisibility of power and control. She says, “The old methods of rigid, hierarchical organization and overt discipline were to give way to a more invisible form of power in which overt conflict between teacher – or parent – and child becomes displaced onto rational argument in which a central trope is the ‘illusion of control’ (Newson and Newson, 1976)” (Walkerdine, p. 210). For example, methods for disciplining students within the classroom spring out of school psychology research and social science methods that are rooted in Baconian scientific method.

For Foucault and others mentioned above, authority becomes a much more illusory and complex idea than Dewey’s. Authority is a property not of “administrators” and “instructors,” but rather of “administration” and “instruction” as discourses. Knowledge, authority, and power become a tangled trio of shared forces within discourse communities. They are not manifest in material objects primarily, but rather social forces that infuse the practices and actions of those of us in the education community and other communities. This sense of “power” advanced by Foucault and others is a productive one – one that becomes the common property of all who would recognize it within their discourse community. Recognizing that power (and the concomitant authority and knowledge) creates space for action.

2.3.3 Apple

Michael Apple (1991, 2000, 2001) adds a dimension to the ways in which we assign value to certain forms of knowledge and their attendant processes (ways of knowing, schooling, and communicating). The social negotiation of what is valuable as
far as knowledge is concerned involves the creation or *authoring* of High Status Knowledge(s) (HSKs) and Official Knowledge(s). Authority is an expression of the values of groups within society; it is a process of favoring certain forms and functions of knowledge; it reflects the moral sway of certain groups at certain times. Apple's constructs are important to understanding how and why authority is linked to values in a process that can emphasize the best of a democratic education and the importance of viewing education and authority as *local* processes defined by the needs and values of the communities doing the education. Apple furthermore adds a mechanism for understanding how authority is tied to politics of exclusion without viewing that authority as a possession of a quantized power. Diverse perspectives that don't appear to fit into Official Knowledge may be excluded or explicitly devalued not as an exercise of the “powerful,” but as a form of community neglect. This highlights the need to constantly be critically engaged in a program of renegotiation of values within the community. In the technology classroom, there is a shifting of the ways in which knowledge and media are valued. This has an important influence on any vision of authority.

Michael Apple's contribution to the field of educational research in political issues, issues of ideology, and authority, cannot be underestimated. Key to the present discussion is his tacit exploration of the issue of authority through a tradition built on the work on ideology and slogans by Gramsci and Greene and democratic education by Dewey.
When Apple speaks of “Official Knowledge,” he usually is referring to a body of knowledge sanctioned by an “authority” that is typically organizational or institutional in nature. Hence “authority” to Apple is consistent with its usage in popular discourse. Still, much of his framework for understanding authority and its effects can be easily transplanted in classroom environments. I am relatively certain that Apple’s form of relational analysis, as outlined in Ideology and Curriculum, would speak to the need to place analyses of the classroom in the broader context of social and political life (and vice-versa).

In perhaps his most well known book, *Ideology and Curriculum* (1990), Apple explores the question “Whose knowledge is of most worth?” This question is ultimately a question of core values of a given group. Instead of being a matter of a scientific deduction, a “natural right,” the question can only be answered by recognizing its context. As Apple points out, “the theories, policies, and practices involved in education are not technical. They are inherently ethical and political, and they ultimately involve – once this is recognized – intensely personal choices about what Marcus Raskin calls 'the common good' (1986)” (Apple, iix). Issues of authority are always, as has been pointed out, tied to values, power, and knowledge. The question of “whose knowledge?” is therefore closely allied to the question of “which/what/whose authority?” In his 1993 book, *Official Knowledge: Democratic Education in a Conservative Age*, he describes “Official Knowledge” as “about who has been and is now seen as a legitimate 'author’” (2000, p. xxxviii) echoing my earlier comments about “author” as the root of the word “authority.”
Apple's work shares a vision of power and knowledge with Foucault, Popkewitz, Cherryholmes, and Walkerdine. Reiterating Foucault, Apple describes “power” as “not only a negative concept. It can of course be used to dominate, to impose ideas and practices on people in undemocratic ways. Yet, it also signifies the concrete and material ways all of us attempt to build institutions that respond to our more democratic needs and hopes” (2000, p. 5).

He goes on to remind us that “education and power are terms of an indissoluble couplet” (p. 44) though I would hasten to call it a quadruplet and would add knowledge and authority to the mix. Apple quotes John Fiske on the relationship of power to knowledge to say:

Knowledge is never neutral, it never exists in an empiricist, objective relationship to the real. Knowledge is power, and the circulation of knowledge is part of the social distribution of power. The discursive power to construct a commonsense reality that can be inserted into cultural and political life is central in the social relationship of power. The power of knowledge has to struggle to exert itself in two dimensions. The first is to control the "real," to reduce reality to the knowable, which entails producing it as a discursive construct whose arbitrariness and inadequacy are disguised as far as possible. The second struggle is to have this discursively (and therefore sociopolitically) constructed reality accepted as truth by those whose interests may not necessarily be served by accepting it. Discursive power involves a struggle both to construct (a sense of) reality and to circulate that reality as widely and smoothly as possible throughout a society (1989, pp. 149-150).

Fiske's comments demonstrate the complexities of understanding specifically how power and knowledge (and authority) function in certain settings, even if we understand that they always are functioning within settings. Furthermore, Fiske's comments, taken with Apple's analysis of “Official Knowledge” suggests that authority and official knowledge are always compromises, always the result of some negotiation of disparate positions. Apple gives the example of textbooks as symbols of “official knowledge” and describes the history of textbook adoption in certain key states like Texas, describing how
the highly political and controversial nature of textbook adoptions ultimately lead to the compromised selection of between two and five textbooks per subject-grade for adoption.

Also important to the current discussion is Apple's “High Status Knowledge” (HSK), of which math and science are examples. According to Apple, math and science have gained “high status” because of their “socioeconomic utility as a form of ... technical/administrative knowledge (Apple, 1985)... In the calculus of values we use to sort out 'important knowledge' from 'less important knowledge,' business and industry, as well as the government, place a high value on knowledge that is convertible ultimately into profits and control” (Apple, 1992, p. 420). As a corpus of knowledge, mathematics has an authority that derives from its hypervaluation as “useful” and “profitable” by our capitalist society. Such “high status knowledge” carries with it a set of social expectations and norms regarding what should count as “mathematical knowledge” and also as a “mathematician” or “mathematically skilled individual.” Those social norms are constructed along gendered, racialized, and class trajectories and have tangible consequences inside (and outside) of the classroom. Apple points out the contradictory situation this places schools in since, “the democratization of mathematical knowledge embodied in plans to teach everyone well... may be blocked by the imperatives of an economic need to produce a limited number of highly qualified students whose ultimate role is to produce economically useful knowledge” (p. 421).

It is worth acknowledging the transformative work done by Paolo Freire, bell hooks, and others to engage in critical theoretical projects designed to right social injustices in education. They are deserving of much more than my little summary here,
and my brief mention of their names is in no way meant to discredit their work. The theoretical framework from which they understood authority was based heavily on a material sense of power (and therefore authority) that is different from what I want to present here. They are, however, in agreement with others mentioned above in calling for the need for real forms of democratic education and the end to oppressive forms of control. They must be mentioned here, if only because they serve as my “action superheroes” who sought to use the space of educational discourse to bring theory to action and action to theory in the pursuit of better communities. They are my reminders that education is always about action. It is my hope that a better understanding of issues of authority and the teacher/student dynamic lead to action in many forms.

2.4 Conclusion

Together, these three bodies of literature will shape a new model or characterization of authority that is more in tune with the issues arising from the prominence of electronic technologies. The frameworks and the tensions produced within/by them in light of educational technologies are the central focus of this project. One of the goals of this dissertation is to develop more useful theories for understanding the student-teacher dynamic, learning as situated, gender and the construction of difference, and active and collaborative learning pedagogies in light of socio-technical change.
The development of these frameworks is inspired by and put into conversation with data collected from a computer calculus classroom where traditional pedagogies like lecturing are minimized in favor of group learning strategies and principles of active learning. In an effort to contextualize the data and their collection, chapter three presents a discussion of the methodology and methods used to gather data.
3.1 Introduction

The previous sections justified the need to reconsider traditional frameworks in light of new technologies. Methodology and research methods must also respond to the current time. But what characterizes this time? Educational research is in a state of necessary and hopeful discord corresponding to the meeting of the modern and “post” modern moments. Educational research methods, conclusions, and assumptions are caught in the overlap of these moments. This overlap forces contests of perspectives that propel the critical intellectual into the role of having not only to seek knowledge, but also to understand how, why, and when that knowledge is sought. The “tools” of research, labeled “qualitative” or “quantitative” can no longer rest on the authority of traditions past, nor on the infallibility of a modern “science.” Feminist philosophers such as Donna Haraway and Sandra Harding have held the monocularity of modern science to the prisms of critical understanding and have demonstrated the ways in which knowledge is both situated and partial. Bonnie Shulman's analysis of the “foundations” of
mathematics point to a system of knowing that is not free from influences of social biases, calling into question the “purity” of perhaps the “purest” of “pure” sciences.

For some, ethnographic methods such as interviews and observations, borrowed from and developed by anthropology, hold promises of substituting “understanding” and “interpretation” for “objectivity” and “validity” as used in modern science. Yet these traditions arose out of the same modern episteme and shared concerns for responsibly capturing the “voice” of the subject. This is articulated through their shared assumptions that the modern human has a personal history and the ability to accurately communicate that history through a language system that is based on the tight correspondence of signifier and signified. Interviews under this view of research struggle to hear “the voice” of “the subject” while observations, falsely classified as “participatory” or “non-participatory,” were the chief tool for recording moments in the visibly knowable world.

Educational researchers now confront a post-structural moment in which “the voice” is at best a collective whisper and “the subject” is at best a tri-partite subject/object/actor. At worst, these two terms participate in the essentialization of human experience based on the modern principles of “difference,” “norms,” and “man” as an independent representative unit of study. At best, they are reflexively troubled in the context of their use in a particular research project.

How then do we proceed? Is it possible to think without the concept of “difference”? Are critical research projects to be grounded only in the lived experience of the researcher in society or can research projects rely on tools such as interviews and observations to “connect” with those whom he claims to research? The purpose of this
section is to bring to light the use of standard methodological techniques as ways of
“unearthing the unexpected.” Linear time having been disposed of in the Western
Tradition by Nietzsche, and in non-Western traditions for millennia prior, researchers are
now in the position of recognizing that linear evolution, especially in the progressive
sense, having guided our concept of learning for at least two centuries, has left a legacy
of expecting the expected. Research projects are often centered on a priori
determinations of what the results should be. Classical notions of hypothesis testing
reflect this inasmuch as the researcher's results merely affirm or deny a hypothesis.
Observed results that depart from a hypothesis signal reformulations of the hypothesis
until testing no longer suggests a difference. Hence the researcher engages in a process
of affirming the expectation of the expected.

Traditional research methods have also been used to bring “realities” to light
through the honest representation of the voices (or experiences) of the participants.
Underlying this effort is the assumption that there is a “true” voice or experience to be
represented honestly by the researcher. Listening and seeing become ways of grounding
research in “the real.” Interpretive ethnologists try to distance their methods from unitary
ontologies insofar as their claims to “the real” are recognized to be approximate maps of
the “real” research landscape. Such research roots itself in the optimistic hope of
mapping human terrain with as little error as possible. The concept of “error,” then, is
based on the ability to appreciate such differences from the “true,” and the inability to
recognize the shifting terrain that is the social landscape. In other words, most
interpretive projects proceed from a static concept of knowledge and “the real” even as they try to escape it. This has been especially true in mathematics education research.

Yet another tension in current research concerns the ways in which language is understood. Language is based on dualities such as presence/absence, and difference. Long before Boole and formal logic, long before the Greek philosophers, language – both written and oral – formulated and obeyed the law of the excluded middle. Research is articulated through language and as such cannot escape theorizing with the concept of “difference” (and consequently theorizing in some essentializing ways). Since interviews, observations, surveys, and document analyses depend on language and assumptions about language, interviews may forever be trapped in a methodological cage, forced to peer through the bars of difference.

3.1.1 So Where to Now?

These methods still may be productive tools for the critical intellectual. Instead of using interviews and observations to give voice to the isolated individual or to describe/interpret the visual, these methods may be used to seek the unexpected and to frolic in the margins of what is known and thought. The recognition that it is both the individual and society who speaks and listens in an interview/observation grounds analysis and helps suggest answers to questions such as: what is it not possible to think without (Spivak, source unknown)? It is difficult to think of human (social) science in the absence of “the human” yet we are in a moment where man’s existence as a theorizing unit is called into question. How then can we proceed to research education as we have
for a long time? To begin with, much humility is called for by recognizing that our tools may not fit a post-structural moment. We must rethink their usefulness and their methodological foundations with deep respect to the Enlightenment spirit of probity that remains a demilitarized zone in the cultural wars.

Part of this “rethinking” involves troubling the theory-practice dichotomy at work in so many research projects. James Paul Gee works at dissolving this split, noting that “any method always goes with a theory... there can be no sensible method to study a domain, unless one has a theory of what the domain is (Gee, 1999, p. 5).” Furthermore, methods of some sort presage domains – one example of this is the way that language itself can be understood as a method that assigns utterances and characters that form “theory.” Theory and practice exist in circularity. This study should not be read as applying theory to reality/practice or as forming theory based on practice, but as bringing theory and practice into constructive conversation within a socio-historical research setting.

Hence, the task of this chapter is to rethink methodology and the assumptions that underlie it, so as to avoid “methodolatry” (Daly, 1986). The categorizing of research into qualitative or quantitative not only betrays an ethical responsibility of the researcher to be open-minded to analysis of the data, it also serves to reify the theory-method (practice) dichotomy in research.
As Gee (1999) notes, “since methods go with theories, there are really no grand categories of research like 'quantitative research' and 'qualitative research' (p. 6).” This chapter is less a roadmap of the course of the research (though there is some of that), and more a reflexive discussion of ethics and principles that both guide and reflect the research.

### 3.2 Ethics

“Sound ethics and sound methodologies go hand in hand.” ((Sieber, 1992, p.4) quoted in (Punch, 1994, p. 94))

The choice of methodology(ies) (and subsequent methods) is grounded in the ethical stance of the researcher and the contexts in which the research takes place. Punch (1994) identifies three developments that have had major impacts on ethical considerations in research. First, “the women's movement has brought forth a scholarship that emphasizes identification, trust, empathy, and non-exploitive relationships (p. 89).” Feminist research has conflated “the personal” with “the ethical, the moral, and the political standpoint (p. 89).”

Second, Punch notes that “action research” has fostered a spirit in which “subjects' are seen as partners in the research process (p. 89).” Partnerships are only maintained through trust, informed consent, and respect for privacy and confidentiality. Research knowledge is seen as a co-construction by the research partners.
Finally, government agencies that sponsor research have come to insist on ethical statements, human subjects review boards, and “monitoring bodies to oversee research (p. 90).”

Hence, research with “humans as subjects” must be concerned with the following issues:

- Informed consent.
- Trust, betrayal, and the use of deception.
- Privacy and confidentiality.
- Recognition of the subject's role in the construction of knowledge.
- Recognition of the researcher's role and biases.
- Responsibility to the data --- “the pen as sword.”

This list is by no means exhaustive. Punch (1994) rightly notes that with regard to ethical issues, there is no prescriptive map. Instead, ethics is a swampland through which each researcher must chart his own course. The ethical course of this study is guided by feminist literature, critical multiculturalism, post-structural literature, and other personal beliefs. Ethical concerns will be discussed in context throughout the description of the methodology(ies) used in the study. If they are to be a meaningful guide to research, ethics cannot be discussed in abstract isolation from the research questions and actions they inform. Relative to the list above, participants, including the teachers and students, indicated their informed consent and were made aware that the study involved no deception. The outline of the research plan was also approved by the Human Subjects Review Committee at the university. Pseudonyms are used throughout to protect the identities of the participants.
3.3 Site

3.3.1 The Physical

A material description of the site is found in the course documentation found on the World Wide Web (WWW). It says that a “typical C&M classroom” has “groups of three or four students sitting around a computer discussing what they see on the screen. Students may come in early or stay late to work around their schedule. There is a lab instructor and an undergraduate class assistant wandering around, aiding the students in discussions about the math” (Calculus & Mathematica, 2001).

This description describes the immediately observable action in the classroom. The classroom itself could be described as a four-walled, white cinder block room with 36 Apple Macintosh G3 computers arranged in four groupings of tables lying parallel to a marker board located at one end (the “front”) of the room (see map below).

Figure 3.1: A map of the C&M classroom.
The room is lit with banks of fluorescent lights from a drop ceiling stained with remnants of water leaks in various locations. On average, 25 students are present for each class. Near the “front” of the room there is a desk with a computer where a “lab assistant” sits. The lab assistant is hired by the university technology center – the body that formally “owns and operates” the facility despite its dedicated use as a C&M classroom. An undergraduate assistant is usually available to help students during class. This person has been through a majority of the C&M classes and has some familiarity with both the mathematics and the software environment known as Mathematica.

The instructors for the course have Ph.D.s though this was not the case as late as six years ago. Students from other C&M classes frequently enter and exit the room during class and often sit interspersed working on their own assignments.

3.3.2 Moving Away From the Physical

On the border of a material- versus virtual- description lies the computing environment. At the time of data collection, the 36 networked Apple Macintosh G3 computers had just upgraded to an operating system known as MacOS 9. To access the machines, students must select their username from a scrolling window and enter a password. They are allowed access to a folder common to the entire class, as well as personal folders they create to house homework and other files. The G3s are loaded with the Microsoft Office suite containing a word processor, spreadsheet, and Internet browser, as well as Netscape's Internet browser, Navigator. They also contain an assortment of other programs including Qualcomm's Eudora e-mail program that students use to send
homework, questions, and messages to each other and to the course instructors. The “workhorse” of the course is a computer algebra package entitled *Mathematica*. *Mathematica* uses a programming language interface to compute solutions, graphs, etc. The package is capable of computing everything from the most basic mathematical commands (1+1=?) to numerical techniques for integration, and beyond into the realm of mathematics done by professional research mathematicians.

The day-to-day functioning of the class usually involved the students first coming into the computer lab to receive some brief (mostly administrative) announcements from the instructor or undergraduate teaching assistant, often having to do with calendar issues like the scheduling of tests and assignment due dates. After that students worked, both individually and in groups, on the lessons. About once every three classes the instructor would lecture briefly (around 10 minutes) on a subject if people had already looked at it and if the confusion on the topic was widespread.

### 3.3.3 Beyond the Physical

Though this material description allows us to paint a mental picture of the space, it is horribly incomplete. Consider this “pictured,” material environment (just described) and now picture it in Bahrain. Now in Auckland. Now in Sowetto. How does the geographic context change the picture? Again consider this “picture” and think of it at a small liberal arts college. Does the mathematics faculty, the administration, the student body, actively support and have pride for the lab and the class? Now picture it in a large land grant institution in a department of 100 tenured professors who are actively engaged
in a research program. Is the C&M project actively supported? Is it a point of pride?

Again picture this classroom. Do reporters visit to describe it as a “model?” Has the

president of the country been to see it? Is it often cited within popular and academic

literature as an example of a progressive initiative? A regressive initiative? The context

radically changes our “picture” of “the classroom.” The material classroom is situated in

shifting webs of relationships to its geography, departmental collegiality, institutional

economic concerns, popular acceptance, educational reform discourse, and other

departments for which it is a service course. The context is overwhelmingly complex,

but has an enormous influence in shaping “the picture” beyond the “point in three-space”

version that is the material description. Current theories suggest a few inroads into the

complexities of context and perception of that context.

In Situated Knowledge, Donna Haraway charts an understanding of perception in

science that attempts to reclaim “objectivity,” but from a “privileged partial perspective”
(D. Haraway, 1988). She argues that we are always seeing from a particular place

through particular lenses. This “place” and these “lenses” are not necessarily physical

locations and objects, but are partially constituted through our prejudices and histories.

We come to different understandings/perceptions/knowledge of the same object based on

different perspectives. Human blood can appear valuable or life-sustaining when filling a

bag at a blood donation center. Pooled in the street next to a gunshot victim, it can be

horrifying. Under the microscope, it can be intriguing, complex, or perhaps tragic if such

a perspective shows the presence of deformed cells. The same object is understood,

experienced, and known differently in different contexts, and from different perspectives.
This has serious implications on attempts to lay out what is meant by “the site” in research such as this. The site includes physical locations, among them the classroom where the course is taught, the offices of the counselors and advisors and the empty classrooms where interviews were conducted. Beyond the physical locations, this research is not simply about a classroom, or even a course, but about the phenomenon of Calculus&Mathematica as I experienced it over the course of two quarters. C&M is:

- An institution
- A system for creating and authorizing knowledge
- A set of practices
- An idea
- An abstraction

C&M exists in a swirl of ideas and actions – it exists in discursive space. Discursive space is the space of socially, historically, culturally, politically, textually, and actively sustained relations. C&M is expressed in its implementation, its curriculum, its reception by students, the ways that students enact C&M knowledge in other courses, its position within calculus reform, the ways in which it changes over time, and the meaning that students, teachers, advisors, and counselors assign it. It is seen, heard, felt and lived. In some ways, C&M is the “anti-site” of research in as much as it exists in the complex mix of discourse and action and the ways that it is extra-physical.

3.3.4 Ethically

Attempts to “define the site” inevitably result in the definition of boundaries. That is, saying that “this is the site” in some ways articulates that “that is not the site.” Hence, defining “the site” narrowly as “the computer classroom” means the exclusion (or
at least marginalization) of other facets of C&M that are important. A student may leave the class each day to return to a residence hall desk to study, to cry, or to pin up a mathematics paper of which she is particularly proud. To push this phenomenon out of “the site” would be to exclude too much of the lived experiences of C&M that contribute to important research ideas. The instructors who choose to teach C&M may be determined by departmental politics or by their status as visiting part time lecturers or professor emeritus. Hence, I afford “the site” a wide and open definition in order to escape drawing a priori boundaries that might hinder responsible, ethical analysis. This understanding of site is predicated on the ethical principle of inclusion. Certain groups, views, feelings, and fields of inquiry have long been hostage to politics of exclusion that betray democratic principles of participation by all. I follow the lead of others such as Sandra Harding (1987, 1998) and Shulamit Reinharz (1992) to return inclusion to its full prominence in social science research.

3.4 Subjects and Objects, Subjectivity and Objectivity

The “subjects” and “objects” of this research fall under the scope of the various levels of magnification or “partial perspectives” mentioned above. Hence, each “subject” – an interviewee, a teacher under observation – is many “subjects” simultaneously and presents multiple opportunities for responsible interrogation and analysis. Similarly, each “object” – documents, classroom space, computer, calculus concept – is multiple objects to be understood from various partial perspectives. The object cannot be assumed to be “outside” the researcher. It is only through interpretation that the object becomes known.
in some form – it is “known into existence.” Likewise, the subject is enmeshed in the same social fabric as the researcher. More than simply being a co-investigator in the research project, the “subject” is always, already engaged in the act of producing and maintaining the social bonds that constitute knowledge. Hence “subject” and “object” are terms that distance the researcher from that which she researches. Here, they are understood to be terms that have either outlasted their usefulness or beg to be called into question each time they are used.

This issue arises in “participant observation,” a method wherein the researcher is recognized as “playing an established participant role in the scene studied” (Atkinson & Hammersley, 1994, p. 248). Atkinson and Hammersley point out that the dichotomy of “participant” versus “non-participant” is not very useful since “it seems to imply that the non-participant observer plays no recognized role at all” (p. 248). Beyond this criticism, the use of the term “participant observation” seems to allow for the separation of the “researcher” from the “research subject” and therefore the dissolution of the inter-subjectivity that exists between researcher and the subjects.

Knowledge is based on partial perspectives, it is situated, and it is based on the severance of the modernist one-to-one correspondence between signifier (subject-object) and signified (phenomenon that can be known and labeled precisely). As such, subjectivity involves the recognition that knowledge is always “subject to” the biases and perceptions of the knower within context. Furthermore, “inter-subjectivity” recognizes the co-construction of partial knowledges; that knowledge itself is a social phenomenon. This is not to be confused with “consensus” which, according to Lyotard “is a horizon
never reached” (Lyotard, 1979, p. 61). Consensus is a goal of dialogue, but it is one that cannot be reached universally. Negotiations of meaning take place locally and result only in local consensus.

Objectivity as traditionally understood refers to the belief that objects may be known in some total and perfect way. It removes human bias from the production and knowledge of a phenomenon – it is the faith of Haraway's “modest witness” (1997) who is merely a vessel through which the final form (in the Platonic sense) of an object is communicated. Haraway works to dismiss the notion that the only alternative to this sense of objectivity is complete subjectivity or, worse yet, relativism. Avoiding the crisis of what she calls “epistemological electroshock therapy” (D. Haraway, 1988, p. 578), she works to tackle the tripartite problem of “how to have simultaneously an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice for recognizing our own 'semiotic technologies' for making meanings, and a no-nonsense commitment to faithful accounts of a ‘real’ world, one that can be partially shared (p. 579).” In other words, the goal is not complete relativism. Nor is the goal the sort of positivist perspective of a neutral and absolute knowledge of an object. Both, according to Haraway, are a “god trick of seeing everything from nowhere” (p. 581). Instead, she calls for an embodied objectivity that reclaims vision, not as a false promise of transcendence, but about “limited location and situated knowledge, not about the splitting of subject and object” (p. 583).

The tools used in Haraway's situated knowledge perspective of objectivity include “mobile positioning” and “passionate detachment.” In the case of the first,
Haraway partially agrees with Harding's standpoint epistemology, noting that “the standpoints of the subjugated are preferred because in principle they are least likely to allow denial of the critical and interpretive core of all knowledge” (p. 584). But she cautions of the dangers in attempting to appropriate and see from the perspectives of others – a form of research “ventriloquism.” Passionate detachment refers to “more than acknowledged and self-critical partiality. We are also bound to seek perspective from those points of view, which can never be known in advance, that promise something quite extraordinary, that is, knowledge potent for constructing worlds less organized by axes of domination” (p. 585). Both principles are used for the purposes of this research as a way of engaging in the practice of research while negotiating the dangers of a subject-object split, a retreat to relativist or positivist fantasies of completely subjective or totally objective knowledge, or an attempt to claim to represent the “true voices” or “true meaning” of the subjects/objects in the study (Derrida's “metaphysics of presence” (Derrida, 1978).) Passionate detachment and mobile positioning remake our methods such as interviews into tools for seeking the unexpected and for bringing the “outliers” back into the theoretical narratives.

3.5 Discourse and Method(ology)

Discourse has come to mean many things in the context of current research. This range of meaning could be thought of as being bounded by three points representing “written text,” “spoken word,” and “human (inter)action” (see Figure 3.2).
Cleo Cherryholmes describes discourse as “what is said and written and passes for more or less orderly thought and exchange of ideas” (1988, p. 2). So for Cherryholmes, discourse lies closer to the written text-spoken word boundary though the “exchange of ideas” has whisperings of human interaction. Yet, in developing the idea of “discourse,” he also recognizes that “practices,” which he describes as “activities performed on a regular basis” (p. 3) though with some variation, go hand-in-hand with discourses. Both exist within “overlapping sets of rules” and cannot be considered separately. He says “no firm, stable, clear, unequivocal distinction can be drawn between discourse and practice” (p. 8). As such, he refers throughout his book to “discourses-practices.” Hence, discourses-practices exist close to the centroid of the above triangle. They involve spoken word, written text, and human interaction. Still, the two-dimensional model presented above is incomplete. The winds of temporality blow through this model’s three-sided window. “Discourses are relative to time and place” (Cherryholmes, 1988, p. 49).
3) just as practices change over time. So beyond the two-dimensional, there is the notion of a dynamism over time and across historical-cultural contexts.

For Foucault, discourses are “practices that systematically form the objects of which they speak” (Foucault, 1972, p. 49). Hence Foucault uses the term “discourse” to include the “practical” or “interactive” component that Cherryholmes includes under “practices.” He recognizes that this is in contrast to popular understanding of the term “discourse” saying, “Instead of gradually reducing the rather fluctuating meaning of the word 'discourse,' I believe that I have in fact added to its meanings: treating it sometimes as the general domain of all statements, sometimes as an individualizable group of statements, and sometimes as a regulated practice that accounts for a number of statements” (Foucault, 1972, p. 80). Foucault's “regulated practice” speaks to the notion that practice is maintained through a system of rules. He furthermore considers as discourse those regulated practices that account for statements. This is an important inclusion of the socio-politico-cultural-historical mechanisms that produce and maintain statements within a given discursive system or institution. For the purposes of this study, the term “discourse” will include related practices.
Cherryholmes suggests that the comparison of discursive practices leads to important criticism, but that Foucault's account of discursive practices works best for “well-integrated and tightly coupled discourses” (1988, p. 87) (such as medicine, education, the penal system). He notes that the recognition of four points “softens” Foucault's argument:

- “not all discursive practices are integrated to the same degree,...
- “when discursive practices and speech communities bump into each other, as it were, meanings and rules for proceeding must be negotiated and established,...
- “anonymous, historical rules governing discourses can be challenged by those not fully socialized to them” (cf. standpoint epistemology), and
- “different background institutions will not police anomalous utterances with equal vigor” (p. 87)

Sara Mills uses Foucault to build her understanding of discourse as “not a disembodied collection of statements, but groupings of utterances or sentences, statements which are enacted within a social context and which contribute to the way that social context continues its existence” (Mills, 1997,p. 11). Mills, like Foucault, thinks of discourses as organized around a principle of exclusion. That is, that rules are established and maintained to legislate what counts as part of the discourse. Mill’s further notes the importance of “truth,” “knowledge,” and “power” to discourses.

According to Foucault, “Truth is of the world... Each society has its regime of truth, its 'general politics' of truth: that is the types of discourse it harbours and causes to function as true” (italics added) ((1979, p. 46) as quoted in (Mills, 1997, p. 18)). Truth is a product of society, culture, and the negotiation of meaning. Hence Foucault's project was not to discover better discourses or “true” discourses, but rather to examine the means by which discourses become dominant and the mechanisms by which they are
maintained and modified. While the means are rarely clear, they are certainly political in nature. That is, they operate according to institutions of power.

One of Foucault's most remarkable contributions comes from his conception of power (see chapter 2). To elaborate briefly, Foucault avoided what he considered to be the 'repressive hypothesis' that “power is simply about preventing someone from carrying out their wishes and limiting people’s freedom” (Mills, 1997, p. 19). According to Foucault, “If power was never anything but repressive, if it never did anything but say no, do you really believe that we should manage to obey it?” (1979, p. 36) This concept of power denies a material economics of power that sees some with, some without, but all in limited supply. Hence power “is dispersed throughout social relations, (and) it produces possible forms of behaviour as well as restrict(s) behaviour” (Mills, 1997, p.20). The behavior that it makes possible, fits Ira Shor's wish for a “power that uses power to share and transform power” (Shor, 1996, p. 20).

Foucault's conception of power has important consequences. First, it escapes the oppressor/oppressed binary by concentrating on the ways that knowledge systems create and maintain ideas that form the bases of action. Second, as Popkewitz notes, it “reverses the traditional belief that knowledge is power and looks for power as the disciplining of individuals as they approach the everyday practices of their lives. It is viewed as inscribed in the rule through which people ’reason' about the world and self as they act and participate. In this sense, Foucault's concept of power gives attention to power as productive rather than as repressive and negative” (Popkewitz, 1999, p.5).
Formulating power this way means rethinking traditional notions of “agency,” or the ability of a person to act willingly according to some degree of self-direction. On the one hand, power is dispersed and held by groupings of people (cf. the “gravity” metaphor from chapter two). Yet on the other, the individual self is inextricable from the social self so the notion of acting on the basis of pure self-direction needs redefinition. Power is productive in that it allows for action, yet, discourse and social membership have regulating effects on action. Rethinking agency requires recognizing that the self is no longer the basis of some form of pure action, nor is it free from the influence and constraints of social interaction. The middle course affirms that the agentic “self” is still a “self” that is subject to the effects and influences of social interaction, yet affects that interaction in personal ways (Butler, 1992). Agency is a guiding principle behind critical, transformational research projects and is important to understanding the sense of “self” and “identity” used in this project.

3.6 Research Question – Methods

*How should we (re)conceive of the student-teacher dynamic and issues of authority in the classroom?*

3.6.1 Reflexivity, Ethics

**Teacher Fidelity**

Having taught a C&M class at the university (studied here) seven years ago, I have had the experience of being “an authority” in this classroom. This both prejudices my analysis and strengthens it since I have familiarity with the pressures, procedures, and
curriculum. I taught a C&M course once at the study university and twice at another university. I enjoyed teaching the C&M classes and saw a great many promises, but also felt the watchful eye of skeptical colleagues (and students). I also sensed that the class seemed to work well for some students though not others, and that those for whom the course worked well were not easily identifiable. It is my own experiences teaching those classes that led to my interest in using the class as an excitation to rethink the ways that I understood aspects of mathematics education (aspects such as authority and the student-teacher dynamic).

My ability to teach C&M the first time was as per a favor from one of the course creators who oversees the program at the university. Since that time, I have developed an amicable relationship with him and he is one of the teachers I observed as part of this study. Though the relationship is amicable and that certainly would lead me to be wary of being “too critical,” I know this person to be very frank (almost brutally frank), humorous, and as open to receiving criticism as I am to receiving it in return. This relationship with the teacher in the study would make analysis hard as “an insider,” yet it also means that there is an established line of communication that I believe functions as a reciprocal and respectful one. If this dissertation were intended as a case study or other form of empirical description of C&M, then the potential for a bad skewing of the data would be more pronounced. As the data are used to put ideas in conversation with one another and to rethink traditional frameworks, I believe this potential conflict is mitigated. The other teacher I studied in this classroom is a peer-acquaintance whom I have known since I first became a graduate student in the mathematics department. He
has been to one or two social gatherings I organized. When I observed him, he was new to the C&M classroom and had an adjustment period that is common for teachers given the different format, goals, and language of the course. He was one of his own best (and hardest) critics in the informal conversations he had with me and is open to conversations that seek understanding of his experiences with the course.

**Student Fidelity**

During the period of observation and interviews, I felt that an intimacy with the students was important given my desire to break out of my assumed perspectives to begin to question ways educators think about issues of authority. Hence, I often tried to distance myself from the teachers and teaching assistants in the class (though I inevitably was asked questions about how to do things – I never seemed to escape the role of “outsider” despite my attempts). Though I was able to distance myself from the teachers in attempt to get closer (more “inside”) to the students, the students seemed to locate me closer to the teachers than to themselves. Though I desired a fidelity with the students, I grew to believe that observations alone were insufficient to form that.

An honest attempt at understanding the experiences of being a C&M student demanded getting closer. I needed to find ways of connecting and promoting trust between myself and some of the students. Trust and connection are ethical burdens of the researcher. The researcher must (usually) initiate efforts to connect and develop trust since they are perhaps the most important components of a research ethics. The development of these connections takes time, patience, and a form of emotional and
intellectual honesty that is difficult to prescribe. The critical researcher must develop trust and connection in the face of constantly calling that trust and connection into question through a process of refraction (more later on refraction). This is a task that requires delicate balance, full disclosure, and the incorporation of the “subject” as a partner in that questioning process.

3.6.2 Especially Relevant Methodological Literature

According to Denzin and Lincoln (1994, pp. 1-17), qualitative research can be understood historically in terms of five “moments”: the traditional period from the early 1900s to World War II, the modernist phase that went until the 1970s, the moment of “blurred genres” from 1970 to 1986, the “crisis of representation” in the mid 1980s, and the present “fifth moment.” During the traditional or first moment, qualitative research is thought of as modeling a “slice of life” as exemplified in the works of Malinowski (1961) and Margaret Mead (1973). The modernist moment was characterized by attempts to formalize methods with continued appreciation of social realism. The third moment saw the proliferation of various genres such as critical Marxism, semiotics, symbolic interactionism, and feminism, and is the moment that gives Clifford Geertz’s often used “thick description” (Geertz, 1973) criteria for validity with the recognition that “the observer had no privileged voice in the interpretations” (Denzin & Lincoln, 1994, p. 9). The crisis of representation was an abrupt turn in qualitative research in which “norms” such as objectivism and subject stasis, were called deeper into question and “new methods of truth and method were sought” (p. 10). The first four moments left
qualitative research in a “double crisis” of representation and legitimation. The authority of the ethnographer was no longer a given, nor was the researcher’s ability to “directly capture lived experience” and the research community's methods for evaluating and analyzing qualitative research. The beginning of the fifth moment brought theories under the domain of narrative analysis in which research (and theory) is viewed as one story among many. Feminist and other critical post-structural projects attempt to answer the “problem of the 'other' in research as social critique and action-oriented research. The fifth moment finds a much greater acceptance of the “posts” such as post-structuralism, and post-modernism (Denzin & Lincoln, 1994).

In his paper “What Comes (Just) After the 'Post'?,” Marcus (1994) answers the question by suggesting that examples such as Haraway's careful return to objectivism (albeit a very changed, reflexive one) symbolize what may come “past the post.” A heavy emphasis on reflexivity and positioning of the researcher within the contexts of a critical view of “truth,” “objectivity,” “validity,” and other “big” ideas in qualitative research mark the moment just after the ‘post.’ Phillip Wexler also attempts to answer what comes “past the posts” by referring to Haraway's objectivism (though not by name) as “a new objectivity of awareness that works through the social limitations of consciousness instead of denying it” (2001, p.20). He calls for a “prophetic mysticism” in the face of the “cognitive schoolhouse.” The work of such a project is “to create a social vision from the mediating revitalization practices by a shared rediscovery of redemptive traditions, both in a study of the traditional texts and in an active renewal of the ancient techniques of self-realization” (p. 22).
Lather (1999) offers “aporism” or a theory of “stuck places” to address ways of reclaiming ethics, representation, and interpretation from among the “ruins of ethnography” (Lather, 1999). Lather suggests that “coming up against stuck place after stuck place (Ellsworth 1997, p. xi)” (is) a way to keep moving in order to produce and learn from ruptures, failures, breaks, and refusals” (Lather, 1999, p.16).

I must confess that I am more comfortable with Marcus' and Lather's formulations than Wexler's return to traditional religious texts, though there are shared visions among them of a revitalized return to objectivism and to exploring shared visions, beliefs, and practices within communities. The goal of this sixth(?) moment is not to tear down science and qualitative research, but strengthen them by bringing the complexities of lived, embodied experience into their domain.

This project, this question, and the others that follow reflect a respect for the paradigmatic stances of critical theory, post-structuralism (for which I share Popkewitz's (1999) understanding of critical theory as having both modernist and post-modern moments – hence I will try to use the term “critical” to mean “critical post-structuralism”), but also for the unseen twists of the current moment in research that fancies fresh approaches such as “angelology” (Lather, 1999), “aporism” (Lather, 1999; Skovsmose, 2000), and “prophetic mysticism” (Wexler, 2001). I agree with Lather that “ethnography under conditions of postmodernity (is) a kind of local action developed in the face of unbearable historicity. An unauthorized protocol, it is a sort of stammering relation to its object that exceeds the subjectivity and identity of all concerned” (1999, p. 27). Moreover, I share Lather's concern that an overemphasis on reflexivity can become
“vanity ethnography” or a means for self-authorization through confrontation of its own processes of interpretation “as some sort of cure toward better knowing” (p. 25). An alternative is “work that attests to the possibilities of its time yet, in the very telling, registers the limits of itself as a vehicle for claiming truth in a way that is an 'opening of a relation to the future' (Derrida, 1996, p. 72)” (Lather, 1999, p. 26).

Research participates in a process of “truth making.” It requires a formulation of, or at least a characterization of, “object,” “subject,” “epistemology,” and “ontology.” This dissertation springs from a philosophy of research that seeks the unexpected, recognizes philosophical 'stuck places' (aporia) as the breeding ground of more questions, and is sensitive to issues of representation and legitimation.

Capturing the “voices” of participants as pronounced truths “can only be attempted by a 'trickster ethnographer' who knows they cannot 'master' the dialogical hope of speaking with, let alone the colonial hope of speaking for” (Lather, 1999, p. 18). This has an important impact on the relevance and meaning of interviews and even observations to the study. Interviews are viewed as performances of interpretations of experiences. The object is not to record as many interviews as possible to better approximate a “collective” or “marginalized” voice, nor is it to “ground” the research in the “real.” Rather, the object is to use interviews and observations as vessels for confronting the researcher's biases and prejudices so as to help the researcher off his beaten paths of analysis on to unexpected or unfamiliar ground. This is the principal strategy used to question the taken-for-granted assumptions within current frameworks. Similarly, textual meanings don't represent a fixed meaning of a text, but interpretations
of interpretations. Researching in the beginning of the sixth moment means researching on uncertain ground. It means trying to think about and without the things that you cannot think without (paraphrased from Gayatri Spivak – unknown source).

Authority and the production of knowledge occur not only within the classroom studied, but within the study of the classroom. The invitation for reflexive analysis is delivered by the situation and must be accepted and attended to. Post-structural approaches problematize “truth” and “absolutes” and reject relativism on the grounds of its similarities to absolutism. The budding theories of the sixth moment invite a return to concepts such as objectivism but only through a reconceptualization that addresses the concerns raised by fourth and fifth moment theories such as critical theory and the “posts.”

3.6.3 Student Interviews

Interviews are often the guiding source of data in qualitative studies. In this study, interviews are mechanisms for creating analytic discomfort as well as making theoretical and methodological inter-connections. This section explores the selection of interviewees, the structure and scheduling of interviews, and validity concerns.

Selection

Selection criteria for the interviews was purposeful and based on the feminist and discourse-analytic traditions that suggest that those who are positioned “outside” the dominant discourse may offer the most insights into that discourse. The two focus
classes included a beginning calculus class and an upper-level differential equations class. In both classes, there were fewer women than men. Moreover, women's relations to technology and mathematics has been regarded as more problematic than men's. The courses are widely populated by those in science and engineering fields, both of which have been studied as socially coded “male domains.” As such, selection was informed by the predisposition to see women as more likely to lie “outside” the dominant mathematical, technical, and scientific discourse – a research strategy supported in the literature by Harding's “standpoint epistemology (Harding in Alcoff, 1993)” as well as variations supported by Donna Haraway (Situated Knowledges,1991).

In questions of “authority” and the discursive production and maintenance of knowledge, the criteria for selection went beyond simply “women.” I wished to find women who seemed to be sensitive to issues of authority and who also seemed willing to engage in critical conversation about the subject. My purpose was not to locate the “modal female student,” but students who I hoped could challenge my preconceptions about the courses and about students’ experiences within the courses. This study regards interviews as a method of seeking challenges to the comforts of discourse analysis, not as a means of providing an “accurate” account of a student, students in general, or women in this mathematics class. Interviews are an ethnographic means of providing ongoing reflexive critique of discourse analysis.

Selection of interviewees was initially scheduled for the beginning of the sixth day of observation. Three interviews were to occur in the beginning of the third, seventh, and tenth (final) weeks of the quarter. Hence, the plan was to have selected interviewees
for contact by the fourth day of class (the first week began on a Wednesday). This proved to be not enough time to meet the selection criteria laid out above. The first three days of class were a “settling period” in which students sought to find a place, make contacts with peers, and establish personal norms for behavior and preferences. Contact was delayed by one week to allow for more observation to inform selection. The scheduling of the three interviews was also adjusted as a result of analysis of the observations and considerations of appropriate timing (this will be discussed in the subsequent section).

**Class One**

The beginning calculus class (referred to as “class one”) met in the early afternoon on a daily basis and initially had 18 males and 7 females, among whom there was one African-American male and three African-American females. The undergraduate assistant was a white female who was a fifth-year senior in civil engineering. The instructor for the course was a freshly awarded Ph.D. in mathematics holding a post-doctoral position while looking for tenure-track work at other institutions. The technology center’s lab assistants fluctuated from day-to-day but were predominantly white males in science or engineering fields.

Students who agreed to participate were informed of the nature of the research, the extent of their participation, and measures to be taken to protect anonymity. They signed a consent form (see appendix) indicating that they understood the details of their participation. As part of informing their consent, they were shown letters from the
instructors of each of the classes indicating that the instructors understood the nature of the study and that students would be participating in the interviews. I further emphasized that I would not be sharing information from the interviews (or who I was interviewing) with their instructor.

_Nessa Rose_

By the third day of class, I noticed Nessa Rose struggling to log on to the network. I was sitting nearby and she asked for my help. I offered all the help I could give and she was defensive, upset, saying “This is a reason why I hate people” (Class One Observation Notes 9/22, page 3). I politely withdrew from the situation back to my seat from which I had been observing. Several others seemed to be having difficulties logging on as well. For this course, inaccessibility to the computer was parallel to being locked out of the classroom in a traditional class. Nessa Rose's frustrations were understandable reactions to being “locked out.” Several minutes later, the instructor asked people to arrange themselves into groups of three people. While most students made a cautious effort to group with people sitting near them, Nessa Rose, who eventually logged in as an “unprivileged guest,” stared intently at her computer, working hard on getting acquainted with the computer environment, but carefully avoiding “joining in.” She seemed to be actively maintaining her “locked out” status. When she was put with a group of three males, she stood behind them (they were seated) and watched them manipulate the computer, saying nothing. On the fifth day of class, Nessa Rose's group seemed intent on carrying out a “divide and conquer” approach to the group assignment, with each person quietly working alone to complete a portion of the
assignment. The instructor confronted the group, saying “You guys are all working on something different. What's going on? That's not a good idea to break them up. Definitely a road to failure. It's best to work together but I'll leave that up to you” (Class One Observation Notes 9/26, p. 5). Nessa Rose's group moved their chairs together and began to work around one of the male’s computers silently. Nessa Rose offered “If someone can explain to me how this stupid software works, I'd be thrilled. You guys decide what you are going to do and I'll go along with it” (Class One Observation Notes 9/26, p.5).

Nessa Rose seemed to be at the center of a rough entry to the class. She felt excluded and seemed satisfied with just “going along with it” as a best-case scenario. She seemed to be having an experience with being outside the production of “official” knowledge and as such seemed to be a terrific prospect for interviews. I sensed that her experiences would offer insights and challenges to my perspectives. As an instructor of mathematics, I did not like my first impressions of her and saw her as a “whiny student” intent on academic self-destruction. I felt that she could confront my perceptions in ways that would challenge my analysis of the C&M experience. Later I would learn that she was a new, first-quarter freshman majoring in psychology and with a keen interest in poetry and literature. She came from a mixed race, military family in a local military town. I came to truly like Nessa Rose and was privileged with the challenges she offered my understanding of the situation. It was my further privilege to watch her change in her approach and engagement with the course over the quarter.
Suma

One of the self-formed groups in the class consisted of three of the four African-American students in the class. The group consisted of two females and one male. Of the two females, one seemed to be extremely confident, expressive, and engaged in the course. I wanted to know more about the ways that the group came together and the ways that their choice of an all African-American group negotiated issues of power, authority, and knowledge. I asked Suma, a self-described first-generation Tanzanian-American, to participate and she happily agreed. Suma's inclusion as a participant was based on my perceptions of her behavior, gender, and race. She was important in that those factors might produce a story that confronted my perceptions of the class from a white male perspective.

Criticism

Nessa Rose and Suma seemed like they would offer unique and important insights into the analysis of the classroom. Their selection was based on my perception of their abilities to challenge my beliefs and to offer critical insight into my analysis. They were both in many ways insiders and outsiders in the class. They did not fit the white male “geeky” stereotype of the “successful” engineer/scientist/mathematician. One possible criticism of this selection is that the challenges offered to my analysis were compromised by the fact that they were selected based on my analysis of their abilities to offer challenges. Perhaps my perception of who might offer challenges is contingent on recognizing certain patterns of behavior and not others as legitimate “challenges.” While
I think there are merits to this criticism, the process of selection is always one of exclusion based on research criteria (unless of course a completely random selection method is used – one that undermines the current research goals) hence it is always political. Whether or not a survey is used to select a sample or nominations on the part of friends, teachers, or other “insiders,” there is always built-in prejudice. My selection of Nessa Rose, Suma, and Ann (description follows) is based on conscious and unconscious ideas, both of which I try to account for in the reflexive component of this methodology.

**Class Two**

Class Two was a differential equations class (the fourth calculus class in the sequence) that met early in the morning on a daily basis and initially had 17 males and 5 females. The class size diminished significantly through the quarter, more so than Class One, so that in the final weeks there were only 3 females and about 7 males attending on any given day. The undergraduate assistant was a self-assured, white male, electrical-engineering student. The instructor was one of the course designers – a white male professor emeritus of mathematics.

**Ann**

Selection of a female in this class was frustrated by the limited number of females (3) attending the class regularly. Two females worked with a male in one group. That group was fairly silent and their interactions with the instructor were friendly but fairly routine. The third female, Ann, was initially in a group with two other males, one of whom was a friend in her field of chemical engineering. Ann was a self-described
“Caucasian” senior undergraduate. Ann immediately exhibited a frustrated but active engagement with issues of authority and knowledge. She actively thought about (and spoke about) the knowledge that she was gaining versus the knowledge her friends had from traditional equivalents of her course. She seemed to be comfortable confronting the instructor and expressing her opinions. Furthermore she gave indications that she was a dedicated student who sought nothing less than perfect marks in the class. Many times her concerns were framed according to obstacles to earning an “A” in the class. This concern suggested that she was a fantastic candidate for learning more about the production of knowledge and its authorization.

**Criticism 2**

Qualitative research often is subject to the criticisms of being based on too small a sample. The question often asked is “how can you generalize based on so few people?” The short answer to this question is that you can't and that this would be an inappropriate (and unethical) use of qualitative research methods (and interviews in particular). Instead of trying to generalize, some speak of “transfer.” That is, can we learn from this something that we can then roughly fit to other situations to understand them better. This seems to me to be only a slight variation of the concept of generalizability mentioned above. This study does not seek the generalization of the ideas from the interview or even the analysis of the rest of the data. In fact, one of the guiding principles for this research project is the suspicion of making claims “for all.” Such claims belie the unexpected turns in social life. Rather, this study seeks to mine the conversations with
these women for evidence that confronts or supports critical analysis of the conceptual frameworks (stated here as problems one through four). Analysis of ideas is the central theme of this project. The interviews are examples of one “shaping” force of this analysis rather than a “guiding” force – they are understood as performances of interpretations of interpretations with multiple, constantly shifting meanings. The number of interviewees is limited in number but limitless in interpretation and the ways that they can be employed to shape analysis. This interpretation is consistent with Steiner Kvale’s criterion for “how many interview subjects do I need?” According to Kvale, “The answer is simply, 'interview as many subjects as necessary to find out what you need to know’” (Kvale, 1996, p. 101). I am confident that this criterion is satisfied given that interviews are used here to unearth the unexpected and to stimulate the reflexive act of confronting research prejudice.

The Structure and Scheduling of Interviews

Inappropriate timing suggested by the research plan demanded an in-study adaptive reconfiguration of the interview schedule. Instead of interviewing at the beginning of weeks three, seven, and ten, two interviews were instead conducted in weeks four and eleven. This allowed the students to have enough experience with the course to have something to say about it, and also corresponded approximately to the times of their first midterms and preparation for their finals. The interviews were semi-structured, with “guiding” questions (see appendix) that were adjusted during the interview based on the responses to previous questions. The use of semi-structured
interviews allowed Suma, Ann and Nessa Rose the flexibility to impact the course of the conversation more than if the questions were fixed. The questions also served as launching pads for communicating my understanding of certain concepts I was interested in studying. The first set of interviews was much more unstructured than the second so as to encourage listening to what each other had to say in the first interview. The second interview, by which time rapport was established, was more structured and dealt with issues from ongoing observations and also with ideas gleaned from the first interview, including a brief member check concerning my interpretation of the events of the first interview. All interviews were tape recorded and later transcribed.

Validity Concerns

Validity is one part of what Steiner Kvale calls the “scientific holy trinity” of validity, reliability, and generalization (1995). Modernist conceptions of validity have been as a measure of the research results' proximity to “the truth.” Something is considered “valid” if it correctly captures the “truth” it studied. Post-modern thought has called into question the existence of a universal and objective reality, hence troubling the modernist conception of validity as a measure of approximation of “the real.” Kvale identifies three frames for reconceiving validity within a post-modern view of objectivity and reality – as “quality of craftsmanship” on the part of the researcher, as a dialogical negotiation, and according to pragmatic standards for ideas in action. The first case, “quality control” calls for a change from the modernist “end of the line inspection” approach to an approach of “quality control throughout the stages of knowledge
production” (p. 27). It involves checking, questioning, and theorizing based on criteria of “quality.” The second approach, “communicative validity,” sees validity as the result of communication and negotiation among those who have an interest in the knowledge claims. The third, “pragmatic” stance focuses “on the relevance of the interpretations for instigating change” (Kvale, 1995, p. 33) and, according to Kvale, avoids the social constructionist temptation to endlessly “circle around interpretations” as well as the postmodern tendencies to devolve into “boundless deconstructions.” As opposed to communicative validity (the second type mentioned above), pragmatic validity “represents a stronger knowledge claim than a mere agreement through dialogue” since it “rests upon observations and interpretations with a commitment to act on the interpretations” (p. 33).

Kvale further defines two types of pragmatic validity according to “whether a knowledge statement is accompanied by action” or whether “interventions based on the researcher's interpretations may instigate actual changes in behavior” (p. 34). Pragmatic validation is further seen as elevating issues of ethics, power, and truth to the forefront of research concerns, recognizing “truth” as whatever helps realize desires by enabling appropriate action to meet them.

Validity, as used here, is not confined to one of the three types mentioned by Kvale. First, quality concerns were at the forefront of the project by including ongoing member checks, questioning based on a growing research experience, and responsible theorizing based on the data. Second, to address communicative validity, participants in the study were shown data and interpretations and asked to comment on my transcription
as well as my preliminary analyses of the data meaning that communication was constant. Hence, validity was addressed with member checks involving the dialogical construction of validity. Finally, an action-orientation approach to validity can be seen in the goals of the research having been clearly stated in terms of formulating an account of the “site” that provoked critical reflection and proposals for action-based change according to notions of pragmatic validity. Issues of power, truth, ethics, and the construction of knowledge don’t just inhabit the foreground of the research picture, they both frame it and fill it. This study therefore uses aspects of all three types of validity mentioned by Kvale. Choosing a single conception of validity would be too dogmatic for a theoretical framework based on great suspicion of singular, universal theories and accounts. Also, Cherryholmes has noted the ways that conceptions of validity are rhetorically produced and argues that validity “cannot be disentangled from history, society, linguistic communities, and power any more than it can be separated from systematic research methodology” (1988, p. 120). Validity is a product of discourse and rhetoric and must be seen as such instead of as a natural, pre-given part of inquiry.

This leads to concerns voiced by Kvale and others for the ways that a “legitimation mania” could lead to “validity corrosion” in which more attention on validation promotes a greater need for more validation, and so on. Validity is an artifact of modernist scientism concerns and is reconceived to satisfy the current need for forms of legitimation. A more comfortable research position would involve “liv(ing) in ways that go beyond a pervasive distrust and skepticism of social interaction and the nature of the social world” by “creating communities where validity does not become a primary
question in social relations” (p. 38). Still, I recognize that we are not yet to the point at which blanket trust exists as a research ethos, and the conceptions of validity as quality, communication, and action-orientation are useful ways of addressing validity concerns within a post-modern context.

Another way in which validity is addressed within this project is through a change in ethnographic metaphors from “triangulation” to “crystallization” (Richardson, 1994). Triangulation arises from the traditions of navigation in which a point in 3-space can be located precisely through three directions. This metaphor is used in ethnographic work to suggest that a phenomenon can be understood (precisely) only through the responsible use of multiple methods (such as interviews, observations, and a survey). Unfortunately, its metaphoric application to ethnography retains some assumptions from its roots in navigation that are less than appropriate in social contexts. First, it assumes that data are fixed (often material) objects that can be understood precisely. Yet we feel that human subjects and histories of their actions and technologies are dynamic, always in motion, always changing. Second, the triangulation metaphor assumes that data are material things in three space, contrary to the framework used here that recognizes the importance of ideas and actions that exist across times and vary according to perceptions. Third, it assumes that data can be understood precisely, which is what Donna Haraway refers to as a “god-trick” – the act of seeing everything from nowhere (D. Haraway, 1988). This is similar to her “modest witness” (1997) who serves as a vessel through which information flows uninterrupted by biases and prejudices. Researchers cannot be modest witnesses.
Richardson proposes to embrace the metaphor of the crystal instead. This metaphor treats data as both fragmented and seen through the prisms of perception as dispersed reflections of phenomena. Figure 3.3 shows a visual model of this metaphor.

According to Richardson, “crystals are prisms that reflect externalities and refract within themselves, creating different colors, patterns, arrays, casting off in different directions. What we see depends on our angle of repose” (Richardson, 1994, p. 522, emphasis added). Instead of locating data precisely, we recognize that the methods we use shape the data that we perceive. Furthermore, what we perceive is not the “data” in any raw form, but refractions of that data. Richardson explains that “crystallization, without losing structure, deconstructs the traditional idea of ‘validity’ (we feel how there is no single [perceivable] truth, we see how texts validate themselves); and crystallization provides us with a deepened, complex, thoroughly partial, understanding of the topic. Paradoxically, we know more and doubt what we know” (1994, p. 522).

Figure 3.3: A visual model of crystallization.
I view this metaphor as a more responsible approach to contextualizing the analysis of the data since it recognizes the limited nature of the tools of inquiry even as it emphasizes the importance of the researcher's situated position within the research process. Validity, then, is less about questioning whether or not the study “measured” what was supposed to be “measured” or even that it “saw what was to be seen.” Rather, combining the ideas of Richardson and Kvale, validity is about quality in craftsmanship, responsible communication of those ideas (in the form of member checks and peer reviews), the actions that are stimulated by the research, and the reflexive recognition of the limits inherent to human acts of knowing as entirely dependent on perspective.

3.6.4 Advisor/Counselor Interviews

After conducting student interviews and a grounded survey, it became apparent that students' prior beliefs about the nature of C&M courses were fairly uniform. To gain more data on the sources of those beliefs, I decided to speak with some of the academic advisors from the school of engineering. I spoke with the “chief” advisor and, based on her recommendations of those who would have something to say about C&M courses, I spoke to two other engineering advisors. I asked all three counselors about their impressions of what differentiates C&M courses from the other calculus options, including a traditional course sequence that emphasizes theory and calculation and a reform calculus course that promotes a graphical, numerical, and algebraic approach to calculus through applied problems. I then tried to ascertain how the counselors arrived
at their characterizations of the different courses. I also wanted to know whether or not there were character profiles of students that would lead them to recommend one of the calculus courses over the others. On a similar note, I wanted to know what informed their recommendations for or against their engineering students enrolling in the C&M courses. All three engineering advisors identified the source of their information about the C&M course as a part of a binder from the counselors in the mathematics department (the advisor's counterparts in the mathematics department). The description of the C&M courses was included in the binder on a sheet describing the various calculus options at the university.

Since one of the sources of information about the C&M courses came from the mathematics counselors, I interviewed one of the counselors on the same topics as the engineering advisors. The mathematics counselors had more knowledge of the historical tensions and developments surrounding not only the different calculus courses, but the communication between the mathematics department and other programs (such as the engineering school) in relation to the calculus courses. Advisors' relationships with students are such that they exert enormous influence over students' preconceptions about what to expect of the instructors in the course. Students may be told that class sizes are smaller, suggesting to them that they may expect more interaction with the instructor for the course. They may be told that their instructor always has a Ph.D., which might lead a student to expect that their relationships with the instructor will be modeled on a different level of authority than if they had a graduate teaching assistant for an instructor.
The interviews were semi-structured and very focused on questions surrounding what informs students' decisions to enroll in the C&M courses versus other courses. Students' decisions about enrollment in the courses are closely tied to issues of authority and the production of knowledge since those decisions help shape the composition of participants in the C&M discourses. That is, the C&M “experience” is informed by students' expectations and perceptions about the course. It suggests the questions: How (and how willingly) does knowledge come to be produced, negotiated, and shared? How is the authorization of knowledge shared or demanded by instructors and students? What happens when students have been habituated into thinking of mathematics classes in a certain way and then are confronted with a different type of mathematics class? What happens when students expect a “different” course and find that those “differences” either don't exist or aren't the ones they expected? Students' beliefs, expectations, and motivations about the C&M courses are important to learning about authority and knowledge. Aside from the student interviews, interviews with the advisors and counselors provided deeper insight into this research question and the corollary questions mentioned in this paragraph. The advisors and counselors were not asked to sign a consent though they did participate willingly, and they were informed about anonymity measures used in this project. Ideas from the interviews were recorded in a research journal for later analysis.
3.6.5 Observations

Observations were conducted on two daily classes: an introductory calculus class taught by an instructor for whom this was his first time teaching a C&M course, and a differential equations class taught by one of the creators of C&M. Observations were recorded in a research journal and later transcribed. Daily observations immediately demonstrated that a “non-participant” research role was not possible (though this was never really a goal). Students saw me not sitting in front of a computer and therefore as someone who was there to assist them. Many did not hesitate to ask me questions about the class, the computers, Mathematica, or the mathematics involved. I tried to answer what I could and what I felt comfortable answering, but I was not eager to become another assistant since those duties would limit my observations of the class as a whole by focusing on a small group of students at any time. I felt that the closer I was to performing the job of a surrogate lab assistant, the farther I was from any chance at being able to observe important situations when they arose. As such, from the start I took as my approach to offer some assistance when it was asked for, but I severely downplayed my abilities to help. Students soon asked fewer questions of me though they were more than willing to be engaged in conversation.

My experiences as an observer could be described as “participant observation” though I am uncomfortable with such a description for a few reasons. First, I was not a participant in the sense of an instructor or an assistant, and certainly not in the sense of a student since I was not engaged in a group nor working on developing the mathematics. As the quarter went on and my abilities to identify observable moments increased, I felt

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comfortable sitting at a computer, looking at the online text and other relevant resources during observations. Doing so further established my fidelities with the students since I was no longer surveying from the side of the room like a security camera.

Instead of “participant observation” I was more comfortable with Eglash's notion of “participant simulation” (Eglash, 1999, p. 183). Participant simulation refers to collaboration in the production of knowledge as opposed to actually living, working, and thinking as a C&M student in the classes. My affiliations with the instructors and my obvious position outside of groups and group work (as well as away from the computers) made participant observation unlikely. Fortunately, the research goals made it unnecessary. Observations were meant to provide accounts of the day-to-day practices of two different C&M classes and a means for watching the ways that the ideas behind the courses (as put forward by the text, the supporting documentation, the reform discourse, the instructors, and the mathematics) were enacted in practice. My level of engagement with the students was not as someone who wanted to be included “as a student” but as someone there to observe, to talk, and to learn as a researcher. I was a participant in that my presence was asserted without shame. I was engaged in simulation (as opposed to observation) in that I collaborated with students and the environment to learn about the C&M classes as they experienced them. They were actors performing the roles of C&M students for me.
It was a simulation in that I was an active audience conversing through a window in their “fourth wall” (the virtual wall that is supposed to exist between stage actors and the audience). I was acting the role of interested researcher observing the classes’ goings-on. There was much more simulation to be had here than observation. Hence, I reject the notion that this was a “participant observation” but instead consider it to be an example of participant simulation.

A later form of observation arose in the form of a colloquium presentation by the courseware creator to the mathematics department. The presentation was an attempt to educate skeptical department members about C&M. The presentation was audio-recorded and later transcribed for analysis.

3.6.6 Document Analysis

Much of the analysis of the C&M discourse comes from the textbooks, syllabi, quizzes, tests, handouts, online documentation that supports the course materials, and worksheets. There was an enormous amount of such material. Though only important for gaining a sense of scope, measuring the quantity of the data is frustrated by several factors. Using a “page” as a unit of measure is problematic since the font size affects the length of the pages. Furthermore, the textbook information is in an electronic notebook as used by the students, but it is analyzed according to the provided “print-outs” of the pages. These print-outs reduce four standard pages to one page so that one page counts either for one page or four. This discrepancy alone leads to the following raw (one page
is one page) count versus the adjusted (one page is sometimes four pages) count (“Calc” refers to “Calculus” and “DiffEq” refers to “Differential Equations”).

Hence the documents ranged from almost 900 pages to more than 3,000 depending on how the count is carried out. While the “exact” count is not really important to the study, it is important to note the extent to which documents were collected for analysis. The major importance of the documents to the study comes not from the number but from the extent to which they provide a context of ideas and assumptions that shape C&M discourse. In this regard, most intense scrutiny was afforded to the downloaded support documents since they established what principles guided the creation and enactment of the curriculum. This study looks at the extent to which these principles also inform the day-to-day operation of the courses.

<table>
<thead>
<tr>
<th></th>
<th>Raw</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calc Lessons</td>
<td>416</td>
<td>1664</td>
</tr>
<tr>
<td>Calc Worksheets</td>
<td>39</td>
<td>156</td>
</tr>
<tr>
<td>DiffEq Lessons</td>
<td>288</td>
<td>1152</td>
</tr>
<tr>
<td>DiffEq Worksheets</td>
<td>24</td>
<td>96</td>
</tr>
<tr>
<td>Indices</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>Quizzes/Tests</td>
<td>33</td>
<td>---</td>
</tr>
<tr>
<td>Syllabi/Handouts</td>
<td>7</td>
<td>---</td>
</tr>
<tr>
<td>Support Docs</td>
<td>42</td>
<td>---</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>860</strong></td>
<td><strong>3194</strong></td>
</tr>
</tbody>
</table>

Table 3.1: Page count for document analysis.
The supporting documentation outlines the ways in which issues of authority and the production of knowledge take place. Therein are the intended goals and guiding principles of the curriculum designers. Discussion of what does and doesn't count as C&M calculus, what teaching is and isn't, what is and is not meant by “learning,” is found in these documents. Conceptions of what “the student,” “the computer,” the “teacher,” and “the mathematics” are found there. The fact that these documents exist in an online medium is important not only to analysis of the selling of the program and the recruitment of students into the program, but also to analysis of how the online genre makes these meanings public – a method for authoring official knowledge or high status knowledge.

Issues of genre and narrative style also suggest the extent to which the knowledge communicated is intended to be “for the masses” as opposed to “for the few.” The clash of vernacular and technical styles in the electronic textbooks is a fitting example of how issues of authority and the sharing of knowledge are communicated through stylistic mechanisms or genres.

Documents are viewed in this study as written artifacts of a time and (virtual) space gone-by. Analysis of the documents is consistent with discourse analysis theories mentioned above, and focuses on the ways that ideas are communicated, appropriated, and enacted. The documents are mined for underlying assumptions, cultural significations, and politco-historical location in “material culture” (Hodder, 1994). The usual difficulty of not being able to perform a member check with a document is
mediated in this study by having access to one of the course designers (and author of the documentation) as well as both instructors for member checks.

### 3.6.7 Grounded Survey

Observations and interviews were conducted during the fall term. In the winter term that followed, a survey was offered to 131 students as part of an attempt to survey all C&M students (at any level in any class) about their experiences. Surveys were only passed out to a class for completion if the instructor indicated that greater than two-thirds of the class was present (though in most cases the instructors indicated that they were missing only three or four students). Furthermore, students were told that the instructors would not see the individual results of the surveys and that they could opt to not participate if they wished. Each student was given a survey and asked to return it face-down in a pile. Students who did not wish to complete the survey simply returned their blank survey face-down as others returned their surveys. Hence, the instructor and I were not able to judge who did or did not complete a survey simply by its being handed in early or noticeably blank.

The survey contained 94 questions, 86 of which were five-point Likert-type items (indicating a range of “strongly disagree” to “strongly agree” to given statements). The items were “grounded” in issues arising from preliminary analysis of the observations and interviews. The idea of a “grounded survey” is well supported by the literature. For instance, Strauss and Corbin elaborate grounded theory methodology as one that grounds methods in an ever-spinning circle of analysis and collection as “practitioners can
respond to and change with the times” (1994, p. 276). The grounded survey was a means of testing for patterns or themes on a bigger scale as they were suggested on the smaller scale. Grounded theory methodology suggests that “theory consists of plausible relationships proposed among concepts and sets of concepts” (p. 278) that leads to theories that are “conceptually dense” (p. 279).

Some of the items included in the survey ascertained student perceptions and preconceptions about the C&M course option including, if they thought it would be easier than other options and if the source of those perceptions could be identified. Another theme on the survey was the means by which students judged their performance within the class, a theme that touched significantly on the ways that students determined how official knowledge was authorized.

Analysis of the survey data was done both by using a computer software package to analyze means, medians, and standard deviations on an item-by-item basis for the entire population and within classes and instructors. Further care was taken to observe the particulars of individual student responses – to try to make a story out of the responses offered by students. For instance, one male student was angered by the several questions about females being better in English or Mathematics and jotted down what seemed to be notes of anger and frustration in the margins of the surveys. The particulars of individual surveys often told stories of their own – it was deemed important not to let such stories become lost in the statistical summaries.

The purpose of the survey then was to add credibility to (or contest) themes as patterns derived from observation and interview data. The intent was not to “discover”
the “truth” about a population on a given item. Here, each item was “significant” in the sense that it suggested multiple stories to be analyzed in tandem with other items. David Fetterman (1989) confirms that while “anthropologists usually develop questionnaires to explore a specific concern after they have a good idea how the larger pieces of the puzzle fit together” (p. 65), there remain “methodological problems associated with questionnaire use – including the distance between the questioner and respondent” (p. 65) and that these problems “weaken its credibility as a primary data collection technique” (p. 65, italics added). Here, the survey is not used as a primary data collection technique and the distance between respondent and researcher is less relevant given that the survey themes were generated from close interviews and observations.

3.6.8 Member Checks

Member checks are a way of addressing ethics and validity concerns within the theoretical frameworks used in this project. Data collected from the interviews were shared with the participants in subsequent meetings in the form of an offer to view the transcripts, and in the form of asking them to respond to some of the themes or patterns that I gleaned from their previous interview. Furthermore, a meeting with one of the instructors and creators of C&M offered an opportunity to have input on the analysis of the data and further discussion about the underlying assumptions and ways of understanding issues of authority.

Member checks add to the level of credibility of the analysis. The reader of the analysis is afforded a greater opportunity for trusting that the results came from ideas in
conversation instead of agendas in isolation. Member checks also promote connection. The researcher and participants are drawn together through opportunities to reflect and discuss interpretation of the data. This promotes mutual critical reflection and therefore addresses ethical concerns about misleading representation and the dangers of various ways of using the data. The participants have a greater opportunity to not just “perform the data” but to critique that performance and to critique the researcher’s interpretation of that performance.

3.7 Timeline for Data Collection and Analysis

The timeline originally forecasted in the research prospectus looked like Table 3.2. It was constructed based on the eleven-week term at the university but failed to account for the fact that the term began on a Wednesday, hence the university week one was only three days long. Furthermore, it made unrealistic predictions about the speed with which selection of interviewees could take place.

Adjustments were made in the field to make the timeline more conducive to the goals of this research. Adjustments included a more realistic time-frame and schedule for participant selection and interviews. Also, the ongoing analysis of data drove day-to-day observations and informed the interviews, but did not provide results that were deemed sufficiently comprehensive to warrant formal member checks. Rather, my daily interaction with the instructors and students served as informal member checks that became part of participant observations. These daily discussions made the fifth and tenth week interviews with the instructors unnecessary.
<table>
<thead>
<tr>
<th>Week:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Ongoing Analysis of Data Begins</td>
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<td>2nd Rsrch. Qttr.</td>
<td>Coding Begins</td>
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<td>Finish 1st Drft Anlys Chptr</td>
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Table 3.2: Preliminary research timeline.

Administration of the grounded survey occurred according to schedule and the second quarter schedule as listed above remained mostly unchanged though the document analysis became an ongoing analysis rather than something that ended in week five. The documents became a constant point of reference throughout the analysis. Finally, the analysis chapter was not written during the tenth week, but became four sections of results that were written into research presentations and presented at professional conferences for valuable feedback and peer review. Also, interviews with engineering advisors and mathematics counselors were added to the schedule due to an in-field recognition of the need for data on student expectations about the nature of the course and their placement within that course.
Hence, the prospectus timeline was changed to resemble Table 3.3. The two quarters mentioned in the table form the primary data collection quarters. The writing and analysis phase of this research had a more general timeline with completion of the first three chapters by June 30, 2003. The results and concluding chapters were completed by August 15, 2003 for presentation and defense to the university community no later than September 30, 2003.

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<tr>
<th>Week:</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Rsrch Quarter</td>
<td>Begin Obsrv Ongoing Anlys of Data Begins</td>
<td>Begin Intvw Selection</td>
<td>Contact Prtpnts &amp; Seek Consent</td>
<td>1stRnd Intvws Ongoing Mbr Chks</td>
<td>Sched. 2nd Intvws Finish 1st Rnd Intvw Trnscrpts</td>
<td>Mbr Chks Cont. 2nd Rnd Intvws</td>
<td>Mbr Chks 2nd Rnd Intvws</td>
</tr>
<tr>
<td>2nd Rsrch Quarter</td>
<td>Coding of Intvws &amp; Obs Begins Trnscr Trnscrb Obsrvs</td>
<td>Grnd Srvy Finish Trnscrpts 2nd Intvws</td>
<td>Anlys Grnd Srvy</td>
<td>Finish Coding</td>
<td>Intvw Advvs and Cnslrs</td>
<td>Anlys Data Prep Prpsls for Conf</td>
<td></td>
</tr>
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</table>

Table 3.3: Revised research timeline.

Following successful completion and defense of this dissertation, the results presented here may be prepared in the form of papers to be submitted to journals for publication. It is my intent to use the data and results of this study to begin building my
publications and professional presentations as a way of sharing these ideas with the professional education community and seeking feedback to refine these ideas for the benefit of mathematics educators.

3.8 Methodological Obstacles

The greatest of all methodological obstacles is the propensity to claim too much. This was, and is the single most difficult part of analyzing and reflecting on the data and what it means to me. “Researching” seems to demand “results” whereas “reflexive” frameworks such as the one I draw from here demand humility and the recognition of perspective. Whereas “research” invites new discoveries of the previously unknown, this research reflects an attempt to engage in renewed inventions of the personally and partially known. As I engage in research conferences and in job interviews, I feel strong pulls to claim big “results” as a badge of research prowess. Holding to my ethical stance regarding what I might responsibly claim “I know” versus “what is known” was the foremost obstacle.

The in-field realigning of the proposal's research timeline could be viewed as a solution to the methodological obstacle of timing and scheduling, though I would much rather construe the in-field adjustments as part of embracing a flexible, reflexive methodology rather than an “overcoming” of something that “should not have been there.” It is part of, rather than apart from, the research methodology.
Further “obstacles” were typical of ethnography and included negotiating entre’,
establishing trust or rapport, and relying on the technology (recording devices primarily)
to work when so asked.

The methodological framework invoked here is a hybrid of articulated
methodologies. Embracing different and sometimes contradictory methodological
frameworks is a multi-vocal approach to the “messy texts” that are the objects of social
research.

3.9 A Few Words on “Criticism,” “Critical,” and “Critique”

The theoretical perspectives present in this research project have roots in (among
other traditions) “critical post-structuralism.” The term “critical” in common usage
invokes a narrow sense of “complaining” or “disparaging.” When someone is “critical,”
we take it to mean that they have negative things to say about something.

Educators have embraced a goal of helping students to develop as “critical
thinkers.” This sense of “critical” is welcomed as a positive kind of thinking – namely
that students are able to analyze situations with an air of suspicion. Critical thinking is a
cautious, self-protective synthesizing of what are often complex situations. It is seen as
something that can and should be nurtured by educators – some educators even go so far
as to claim that it can be taught or perhaps “developed.” (Appelbaum has written an
excellent discussion of the idea of “teaching” critical thinking as a set of skills
(Appelbaum, 1999).)
So “critical” is seemingly trapped between its common “no one likes a critic” use and its use in educational discourse as a form of thinking we would like to see our students develop. The term “critical theory” seems to be perceived somewhere in the middle. I would like to call for a renewal of the adjective “critical” in research and education as a form of reflective suspicion infused with desires of rebirth, transformation, and renewal. Though “critical theorists” come in many forms, a desire to hold ideas and actions to the candle of suspicion so as to transform them according to new perspectives seems to underlie most of them.

Unlike a movie critic or food critic that seeks to judge according to a single standard and to offer that judgment to others as some accurate, community-wide representation of value, critical post-structuralism is self-suspicious and avoids making big claims for big groups of people. Critical post-structuralism critiques its own measures of value, applicability, and “transferability.” As such, I think the term “critical post-structural theorist” is potentially a big umbrella term, and that mathematics educators, slow to adopt or recognize these frameworks, have much to gain through their embrace.

3.10 The Dissertation Format: Analyzing the Medium

Writing a dissertation is many things. It is a first attempt at a major research project under the watchful eye of advisors and supporting professors. It is also a document that serves as evidence for accrediting its author as deserving of a philosophical doctorate. It is a self-written invitation to join a community of scholars and
to participate in the dialogue of educational research. It is a testament of personal achievement, confidence, and satisfaction. It is several drafts, several reams of paper, and a few ink or toner cartridges. It is, according to the ideas of Laurel Richardson (1994), more than a record of research already done, it is research in the doing. More than a set of footprints through the research landscape, it is the walking (dancing, running, stumbling, or crawling).

This document is never finished writing itself as a palimpsest of interpretations. There is no space reserved for it on the bookshelf of discourse – it fights for attention and meaning within the broad space of educational discourse. Format concerns, university rules for its production, and personal and political forces limit what it might say and how it might go about saying it even as though same forces nurture and guard it. The politics and regulations tell the story in often unpredictable ways, like a brisk wind randomly turning the pages back and forth, upsetting the linearity of the narrative. The wind carries the productive potential of power and politics – Foucault's “power” – and I embrace it not only in my analysis of the data, but in my respect for the untraceable and unpredictable interpretations that it might provoke in its readers. The dissertation is not an ultimate exegesis of the research site and it will yield itself to no final exegesis. It is but one layer sedimented within the ever-eroding crust of ideas on gender, power, technology, mathematics, and education.

Driving each step in the writing of this document are my personal hopes that my imagined reader will be inspired by its words. I wish for its sentences to be felt as actions that rewrite, rethink, and renew lived experience. I hope that its “impact” is more like a
spring shower that forces a smile as the landscape renews itself as opposed to a violent tornado that remakes the landscape into a patchwork of littered scars.

I hope that the reader sees things in this dissertation that I did not see and that it invites some reflection on educational practice, mathematics, and technology in society. It is a technical report, a tool for accreditation, and a struggling first shot at something new. Its pages trace the history of production through its letters – each “o” wears a face (sometimes smiley, sometimes distraught), each “n” is a hill that I had to climb, and every comma was a stake driven into the document's mountainside to serve as a foothold for advancement. This is a story of the productive power of rethinking the taken-for-granted.

3.11 Conclusion

This chapter offers a methodological framework as a way of interacting with data's scattered prismatic shadows. The ethics of responsible, honest engagement with the ideas and actions of the site drive a hybridized framework. The framework is a constitution of flexibility and responsibility – one that was interpreted and reinterpreted on a moment-to-moment basis throughout the study and analysis. It is enacted as a study of ideas and actions situated in the context of reflexive analysis of a set of educational practices and ideas. Observations, interviews, documents, surveys, are seen as methods for stimulating suspicious criticism of the ideas and actions that were part of C&M. The suspicious criticism leads to a cautious thinking through the “things without which I cannot think,” which in turn leads to a research report that, like Richardson says, exhibits
how we “know more and we doubt what we know” (1994, p. 522). This is not a paper on practice and it is not a paper about theory – it is a paper whose very writing deconstructs the theory-practice divide as a form of segregated knowing. What is learned from this project is learned by frequent and playful crossings of knowledge's territorial boundaries.

This dissertation's validity has yet to be judged since it is “validated” through its stimulation of action, thought, and the restructuring/renewal of social practices. It is a report that seeks questioning as an appropriate answer to research questions. Spelling out a methodology is not the same as writing down a set of directions or a recipe since the research terrain is ever-changing. This chapter doesn't articulate a grammar or vocabulary for research practice, but instead offers itself as an alphabet of ideas that are joined together to create a sonorous “humming” that backgrounds the dance of research.
4.1 Teacher and Student Roles

Teachers and students are the principal actors within education. Though there have been multiple currents in education that have influenced models of the relationship between teachers and students, common across all of these models is the idea that teachers are the ones responsible for ensuring that learning takes place for/by/within students. The relationship between teachers and students traditionally has been modeled on an extreme imbalance of power, with “the teacher” coded as the more powerful, knowledgeable role. The issue of power and authority may have as yet unexplored consequences on many issues related to teaching and learning, such as self-efficacy and identity concerns.

Classrooms today feel an enormous influence from national discourses in educational reform that, for the most part, advocate seeing students as “active learners” and “co-constructors of knowledge.” Still, the teacher remains the site of authority for discipline, assessment, direction, and judgment of what counts as valid knowledge. This
model is deeply encoded in our ways of talking about schooling and education. Consider that for the nouns “teacher” and “student,” only “teacher” has a verb-form: “teaching.”

Seeing the teacher-student relationship according to an extreme imbalance of power has a very palpable impact on educational research and on classroom practice. Reform efforts that are based on such a vision will tend to see the teachers as the primary (human) sites of change. Hence changes in educational practice (pedagogy, curriculum), will be exercised on students by teachers, administrators, and educational researchers. Furthermore, policies such as those that intend to improve educational outcomes by instituting annual tests of teachers are based on a vision of the teachers as those most responsible for learning.

There are good reasons for modeling the teacher-student relationship as one wherein the teacher is disproportionately powerful, knowledgeable, authoritative, and responsible. To begin, it is a broad-based hierarchy wherein one leader (the teacher) has “under” her a great many students. Delivery of services, assessment decisions, curricular changes, and administration are made easier when one person is responsible for a great many.
Also, teachers are, in many ways, more experienced and in some cases more knowledgeable than their students (so long as we can agree on what counts for “knowledge”). As a parent, I hope that my child's teacher is a skilled and creative professional who can exert influence over my child. This model of the teaching-student relationship has a long historical basis in Western education and seems to have been “normalized” and “institutionalized” to the point that the assumptions behind the practice are simply accepted out of hand by politicians, parents, educators, and the students themselves.

This “core” of a model, while dominant in educational theory and practice, is by no means universally accepted. Yet throughout the western history of education, it is this view of the teacher-student relationship that forms the core of almost all models. Differences between current “student-centered” approaches and the dialogues in Socrates' gardens seem to be mostly rhetorical. Current “student-centered” approaches in mathematics education, such as group learning activities and hands-on materials only change the face of the educational currency. The teacher remains the provider of the environment, the tools, and the learning goals. The Socratic method, which will be handled in detail later, insists on the active involvement of the student, but the questions posed and the directions taken remain the province of the teacher.
4.2 Enter the Computer

With the growing role of computers in the classrooms, it has become imperative that we question the taken-for-granted assumptions behind traditional frameworks for understanding the teacher-student dynamic. Knowledge inhabits the same space as information, and information technologies have become commonplace in education, so it seems appropriate and necessary to question the ways in which the technologies have changed the space of knowledge, learning, teaching, authority, power, culture and politics of schooling, and national and international influences/impacts.

4.2.1 Authority and Officiating Knowledge

Authority is Important

While schools serve many functions, the issue of how authority is constructed infuses almost all of those functions. As an accreditation body, the school has an authority to decide what constitutes a level of accomplishment necessary to earn certification or a degree. This authority is distributed to administrators, departments, and instructors so that its effects may be felt throughout all aspects of schooling (at any grade level). A spelling test over words pertaining to African geography is ultimately intended as a means of "measuring" whether or not a student has gained proficiency in a certain area. Spelling tests lead to grades which ultimately lead to a student passing (or not) to the next subject/level.

Furthermore, enculturation and acculturation functions of schooling rely on the instructors, the curriculum, and the institutions of schooling as "social and cultural
One often mentioned function of schooling is to promote an “informed citizenry.” Presumably this refers to a population that is capable of participating in daily life, in making decisions on all matters, and in becoming “productive.” The conventions, habits, and codes that make this possible come not only from parents, but, very importantly, from schools. Schools shape an individual's perception of their place within their communities and the world. That the institution of schooling continues to serve this function (to varying degrees of success), attests to the trust of the citizenry generally that teachers and schools have such an authority. This demonstrates that such an authority is often granted by a majority consensus – actively or inactively as “convention.” It also offers one explanation for increases in the number of home-school and charter-school children in America – very often these “charters” school according to a social and cultural perspective that differs from mainstream schooling. Nevertheless, the school has a social, cultural, and political authority with far reaching impacts.

Within the classroom, the teacher represents a disciplinary authority. It is the teacher that is ultimately responsible for the rules and conventions that guide classroom exchanges. As “facilitator,” “dictator,” or “nurturer,” the instructor assumes the responsibility for sustaining environments that support given learning outcomes. The management component of this responsibility requires that the teacher be the “final word” in issues related to discipline and the structure of proceedings within the classroom. The teacher's age, experience, and education position her as able to assume classroom authority. That authority exists through the consent of students within the classroom and the support of parents and administration outside of the classroom.
Hence, “authority” can be thought of as a socially granted power to “author” environments, actions, principles, habits, and rules. An authority is someone (or something) that is granted certain powers by virtue of a set of socially constructed criteria. Authority infuses classrooms, schools, and even the idea of schooling in ways that have become unquestioned assumptions; the “granted powers” that form authority have become “taken-for-granted powers.” It is past time to reawaken discussion of the concept of authority in schools and schooling with the hope of finding hidden avenues for improving education. First, however, we must investigate options for understanding the concept of authority.

4.2.2 What the Computer Does to/with Authority

The National Council of Teachers of Mathematics (NCTM) Principles and Standards (2000) document includes a “technology principle” as one of its six principles. They argue that technology (computers and calculators in particular) is essential to mathematics education, saying that they are useful as tools for visualization, organization and analysis of data, and “efficient and accurate” (p. 24) computation. Furthermore, they assert that technology supports most areas of mathematics and affords students the opportunity to “focus on decision making, reflection, reasoning, and problem solving” (p. 24).
The *Principles and Standards* suggest that technologies:

- enhance learning by “providing a means of viewing mathematical ideas from multiple perspectives” (p. 25);
- support effective teaching by allowing the teacher the freedom to circulate and engage in process and product assessment; and
- influence what mathematics is taught since, for instance, computers can make large data sets accessible to elementary school kids (through the construction of graphs and charts).

While the NCTM clearly recognizes the importance of technology to the mathematics classroom, the technology principle is important both for what it says and what it doesn't say, especially regarding authority. To begin with, the need to “re-examine the mathematics students should learn as well as how they can best learn it” (p. 25), would be a terrific byproduct of introducing technology to the mathematics classroom. The problem is that technology hasn't really changed the mathematics, but rather it has only shifted around the order in which topics were taught. Instead of questioning the need for teaching techniques of graphing sine and cosine functions, technology has just allowed the introduction of the trigonometric functions and their graphs much earlier in the curriculum. The corpus of “important” school mathematics content remains unchanged and authority remains obscured.

The technology principle as articulated by the NCTM urges that technologies be used for what they “can do efficiently and well – graphing, visualizing, and computing” (p. 26). Nowhere in this principle is the computer discussed as providing a new
networked and distributed mode of communication. One of the palpable ways that technology has influenced authority is that Internet connectivity has allowed wide access to Web-based information, e-mail, video e-mail, online chats, forums, and discussion boards as new ways of communicating with others outside (or inside) the classroom. The Danish ambassador to the United States may now be nearly as easily consulted as a geography teacher. Multiple explanations, modes of representation, and viewpoints are but a click away, expanding opportunities for a more diverse classroom.

So why isn't communication included in the NCTM technology principle? Perhaps one of the assumptions that remains unexamined and unreformed in the face of technology is the authority of certain styles as acceptable modes of learning mathematics. Mathematics may be perceived as a subject for individual study, one that is done through the manipulation of symbols on a page instead of the exchange of words with others. Communication may not be a value that is central to current mathematics pedagogy – an idea that may explain why communications may not be perceived as an important benefit of computing technologies in the mathematics classroom. Inasmuch as textbook companies consult the NCTM Principles and Standards, this could have important ramifications for the pedagogies and content that is codified and authored into “official mathematical knowledge.”

Another important impact of this omission concerns teacher professional development. Computing technologies could be great assets for communicating and participating in discussions with other teachers, teacher educators, and professionals in the development of better pedagogies, activities, and content knowledge. The teacher’s
authority grows stronger through a networked distribution of responsibility and authority through others she consults via the Internet and the World Wide Web. A good technology principle should support that goal.

The NCTM technology principle is, for all that it lacks, fairly representative of the ways that many classrooms currently use and view technology. The mathematics has changed little though parts of it may have been reassigned value and moved to different locations in the curriculum. The communication aspects of computing technologies are being underused despite the fact that the technological know-how exists to support it. Professional development (what traditionally could be seen as an exercise in strengthening authority, knowledge, and power) remains unsupported within the principles of the NCTM.

The current generation of teachers has, for the most part, had to consciously learn about the computing technologies with which they teach. They didn't grow up with complex video games, personal digital assistants, and video-streaming. In contrast, many of today's students have grown up accustomed to carrying on four or more conversations simultaneously via instant messaging while talking on the phone, watching television, and eating Easy Mac. Students come to the classroom knowing, in many ways, much more about the computer than the teachers do. Asking the student to complete an online tutorial about slopes and linear growth may be cutting-edge for the teacher while being a truly boring use of technology for the student. The teacher may have to share that facet of authority dealing with computer know-how with the students, making teachers and students uneasy as the traditional model of teacher-student authority crumbles byte by
byte (Stensaas, 1999). Students may begin to doubt the wisdom of the teacher in computers and in mathematics, while the teachers may simultaneously doubt the beneficence of the computer in their classroom as they watch their control erode.

The traditional model of teacher as expert/authority and student as learner/novice is, today across the country, being contested and deconstructed largely due to new technologies and new modes of communication. It is essential to provide educators with new options for effective models that adequately address technology in the classrooms. Authority is central to this phenomenon. The mathematics education community, despite being quick to embrace the presence of these technologies, has been slow to account for their effects on pedagogy and classroom dynamics. (n.b. The pervasiveness of these technologies outside the classroom is just as important, if not more, and should also be considered when trying to understand issues of authority and education.)

Another important effect of computational technologies on education currently is the impact felt in policy discourse. The use of computers and calculators in K-16 education lies at the center of a national debate that is superficially about basic skills versus conceptual understanding, but more deeply about who gets to say (author) what counts for important (official) mathematical knowledge. Politically, the opposing sides in this debate (popularly called the “math wars”) are divided along the lines of a more conservative, reactionary longing for mathematics as they were taught mathematics (a drill-based pedagogy and facts-based curriculum), and a view that mathematics education requires reform principled on conceptual understanding and broad exposure to many mathematical ideas. It would be interesting to study the political party affiliation or
voting habits of those who debate the “math wars” to note whether or not the reactionary-or reform-minded values advocated in the math wars mapped onto voting preferences (see Bucci, 1999). Our concern about issues of authority is strongly political in nature, and situated within a complex social discourse. The effects of technology in this discourse, and therefore in policy-making are being strongly felt. Michael Apple's conclusion that official knowledge is always a compromise is echoed in the NCTM technology principle in phrases like “Students can learn more mathematics more deeply with appropriate use of technology (Dunham and Dick 1994; Sheets 1993; Boers van Oosterum 1990; Rojano 1990; Groves 1994). Technology should not be used as a replacement for basic understandings and intuitions; rather, it can and should be used to foster those understandings and intuitions” (p25). The use of the phrase “basic understanding” reflects a reaching out to those opposing NCTM reforms and advocating a “back-to-basics” approach.

The impacts of technology on authority and knowledge are already being felt inside and outside of the classroom. The current state of authority and technology is one of extreme tension. On the one hand technology is coded “essential” for the mathematics classroom, yet in its application, teachers and students are confronting problems (largely due to inadequate models) adjusting pedagogy, content, and the social structure of the classrooms to the new technologies. Politicians, parents, and educators recognize the importance of computers and calculators yet struggle to figure out what impacts they could or should have on what counts as mathematics (and also who gets to decide on what counts for mathematics). Communication technologies advanced by computers and
the Internet are redistributing authority by opening access to new resources, yet teachers and students are unclear about how to assign relative value to competing resources in the face of a newly recognized diversity of (often disparate) knowledge(s) brought into the classroom via these communication technologies. One goal for this dissertation is to offer a new theoretical framework to help parents, politicians, and educators address issues of value and implementation of new technologies in the mathematics classroom. The next section addresses the ways that authority could change in light of technology.

4.2.3 What the Computer Could Do to/with Authority

As already mentioned, computing technologies are already influencing the ways in which authority is distributed or assigned. At this point, this redistribution of authority is met largely with resistance or minimally with extreme caution on the part of teachers, parents, and students. The potential does exist, however, for a radical redistribution of authority, to a degree that may not yet be foreseeable. For instance, one extreme might be represented by a total equalization of authority, in which the teacher and students share in the authority to assess, to make curricular decisions and to decide what constitutes official knowledge. Though I think this to be unlikely, it does represent one extreme, and I think it is a direction in which technology seems to be pushing the dynamics of authority.

Uncertainty often breeds distrust, making it difficult to advocate the revamping of the traditional authority structure within education. Such a position could be seen as promoting the “deskilling” or “deprofessionalization” of teachers. It could be seen as yet
another mandate from atop the Ivory Tower that is, in practice, too complicated to institute. Nevertheless, I believe there are benefits to restructuring curriculum and pedagogy (and policy) to explore new ways of authoring, authorizing, and officiating knowledge. I premise this position on the well-supported belief that education is: social (embedded in inter- and intra-personal, as well as material exchange), political (involving a constant interplay and negotiation of power), local (tied to community and cultural practices that are geographically and temporally remote), and economic (creating and reacting to the ways that resources are distributed throughout populations).

Once physical access to computers and the Internet is achieved (an accomplishment that is not currently realized everywhere, but certainly under way), then access to information from many resources becomes a possibility. This so called “democratization of information” is currently understood to be a condition in which everyone has access to information. What is lacking from this conceptualization is the ability of everyone to have input into negotiating which information is most valuable, thus changing the nature of that information. That is, a true democratization of information should involve not only access to pre-existing information, but also the ability to change and re-value that information.

Applying this to classroom settings, technology could be used to encourage students to contextualize new knowledge in personally meaningful ways. Technologies could be set up in such a way that students are brought into communities of practice and the knowledge of cultural and social discourse in ways that allow multiple approaches to shared beliefs and practices. Instead of learning about the World War II in which the
101st Airborne bravely fought the Battle of the Bulge, sacrificing the lives of many working-class, white Americans, a Navajo student in Window Rock, AZ, could use the Internet to uncover the World War II history of a great-grandfather, a code-talker, that brought victory in Japan. Or a Japanese-American student could learn the World War II history in which her American great-grandparents were interned within the U.S.A. for the duration of the War. There are three histories, all of which are local, culturally meaningful histories of World War II, though the relative valuation assigned to certain events as meaningful changes from history to history.

Within the mathematics class, Hispanic students might use technology to learn about their shared ancestry with the Aztecs who had an immensely complex and rich mathematics. The United States of America has an incredibly diverse population, making it the challenge of all educators and students to shape an education that situates the students within a meaningful context, and that recognizes the students as authorities – as authoring their lives and their place(s) within the world at large. Seeing oneself as having a history of mathematical use and development (as seen in the Aztecan example) is one way of using technology to find and create authority as an alternative to the classroom teacher, the history book, or the images of who a mathematician is (or what constitutes mathematical knowledge and practice). A deconstruction of authority is necessary to achieve this – the teacher must shed control over what counts as important knowledge and the path to that knowledge. I don't think this means “losing control,” as will be discussed in the next section. The teacher is an invaluable resource for seeking direction.
Hence, pedagogy, curriculum, and what counts for valuable knowledge, change according to the reconstruction of authority as a result of technology. Understanding the nature of that change and shaping that change could lead to finding ways to educate teachers, parents, and policymakers to embrace technologies that allow the sharing and community construction of authority for a wider range of people. We could find new ways of approaching so many organizations' calls for an education “for all.” Having now understood the ways that technology creates a need for a new model of authority, the next section posits a new model for understanding authority.

4.3 Towards a New Model of Authority, Knowledge, and Power

The first section of this chapter outlined the ways that technology has created a need for a new model for the student-teacher relationship. Currently, the fundamental concept that distinguishes the difference between “student” and “teacher” is the nature of “authority.” Computers and other technologies are fitting poorly within the existing student-teacher dynamic and cry out for new ways of thinking about teaching and learning. To do this, we must find new ways of thinking about authority. The theorists described in the second section of this chapter suggest some ideas for alternative models for authority.

I propose a new model of authority for education that addresses some of the problems mentioned earlier. I then generate from this model some criteria for evaluating change in the face of technology, offer some constructs that may be useful in
reconfiguring authority within education, and then use this collection to look at a particular instance of technology involving using computers to teach calculus.

Traditional approaches to authority view authority as a property – a license to act in certain ways, a currency to be granted and taken away, or a material object that embodies certain valuable characteristics. Technology and modern forms of communication have shown this to be inadequate. A new sense of “authority” is marked by the following:

- **Authority is a process.** It is a constant negotiation of power and values. It exists as a performance by groups of people according to compromise and consensus.

- **Authority is productive.** It involves negotiating order and structure. It involves recognizing and valuing knowledge and forms of knowledge from a vast array of resources – a process that is the privilege of all people and therefore a social force that could be used by all people to produce change.

- **Authority is articulated through power and knowledge and punctuated by gender, race, and class.**

- **Authority is about the power to assign value to certain forms and sets of knowledge above others.** In Fiske's terms, it is about two things: “control of the real,” and discursively constructing [that] real as the truth (Fiske). In Apple's terms, it is the process of defining and redefining “High Status Knowledge.”
• Authority exists in tension with freedom, and authority and freedom are paired with stability and change (Dewey, 1936).

• Authority is both overt and covert. It operates blatantly as when grand tensions erupt over the place of evolution in high school science curricula, yet it also operates stealthfully each day as we send our children to school --- their simple presence in the classroom as a tacit consent for the school to organize and foster learning of certain knowledge in specific ways.

This model is a model primarily of characterization, of recognizing and understanding authority. “Authority” defies being modeled as a “how-to” according to a flow chart – its highly complex and interrelated status as a process can not be broken down into step-by-step instructions.

The model has important implications for educational practice. To begin with, since authority is an ongoing process, it is not a pre-ordained hierarchy of power. The axiomatic assumptions that once defied explanation (such as that the teacher is the “expert” and the student the “novice/learner”) now beg for a much more explicit recognition of who possesses what/whose knowledge and how is it shared (with whom)?

Technologies, and in particular the computer, must be thought of as more than a tool. Tools are controlled by actors. Computers are more than machines to be controlled by “users.” They are means by which we represent ourselves, our identities, and our knowledge to others. The computer expresses a set of values for what counts as important knowledge. So the model of authority advocated here is not only the result of a
change brought about by computing technology, it also changes technology through a recategorization as more than a tool. The computer is an extension of the person. It authors our knowledge in active ways, shaping, for instance, the ways that the brain and learning are defined in information processing terms (Atkinson and Shiffrin, 1968).

Mathematics also participates in authority. Mathematics is a cultural construct that is coded as “logical,” and “unbiased” and therefore is part of the process of justifying truths according to the rules of a scientifisco-mathematical authority. Both overtly and covertly, authority prescribes rules for appropriate uses of mathematics as mathematics simultaneously authorizes the rules by which authority exists in many discourses. Mathematics is a “High Status Knowledge” because it is a highly valued form of authorization. Mathematics is bound reciprocally to authority in the same way that technology is bound reciprocally to authority.

4.4 Criteria for Evaluating Effects of Technology: Authority, Power and Change

Given this model for authority (and therefore a new way of thinking about the student-teacher dynamic), what criteria can we use for judging implementations of technology that work toward a better student-teacher relationship? The criteria offered below are meant to be a starting point. I welcome additions, changes, and suggestions to what follows. I intend to make them as broad as possible so as to give them a wider sphere of application. The criteria arise from the conversation between the data and the theoretical perspectives mentioned in chapter two. For instance, several of the criteria are related to concerns for democracy in education as elaborated by Dewey. Those concerns
were echoed in student interviews and observations, with students recognizing and
confronting limitations on their abilities to act and to make changes to the classroom
practices. Other criterion stem from personal experience and observations of the C&M
classrooms. For example, the recognition that the technology/product being used must
ultimately facilitate the learning goals and that an effective form of assessment must be
aligned with pedagogy, technology and learning goals.

4.4.1 Criterion 1

*By whom is this technology constructed, and what degree of freedom do the users
have to reauthor the technology?* Software and hardware production are today highly
centralized efforts, with most educational software coming from only a small handful of
companies. Software licensing and proprietary protection mean that while a piece of
software may be highly configurable, it is also written with an extreme eye towards
controlling and limiting the types and scopes of reconfigurations. Software and hardware
should be as “open” as possible so as to allow students and teachers as much freedom as
possible to reauthor the technology to fit local needs while still protecting the financial
and intellectual interests of the technology's creators.

4.4.2 Criterion 2

*To what extent does the technology allow for the appropriation or sharing of a great
diversity of possibly disparate knowledge? To what extent does it order, organize, or
regulate the relative value of different forms of knowledge?* The language of the Internet
is English; not Spanish, not Swahili. Even though the machine language is one of presence and absence of electrical charges, represented mathematically as 1 and 0, the Internet and the computer don't really embrace the representation or symbolizations of mathematics, allowing for the easy construction and sharing of graphs, formulae, and arguments requiring intense notation. When the computer and the Internet speak English, knowledge of English speaking countries, stories written in English, and online communities speaking English are operating within more highly valued (as an aggregate) systems of discourse. When the primary sense invoked by the computer is that of sight, certain forms of knowledge are being devalued. Openness to diverse forms of knowledge and the allowance of changes to support revaluations of knowledge and its expression are key ways in which technology can articulate more productive instantiations of authority.

4.4.3 Criterion 3

To what extent is the technology culturally, socially, economically, sexually, racially, and politically transparent? To what extent does the technology incorporate a mechanism for self-reflection? Technologies are palimpsests. They are media with and upon which we author personally meaningful knowledge and representations of ourselves. The ways in which technologies distort that representation must be exposed and made transparent. While I would never argue that technologies could be socially, culturally, politically, or otherwise neutral, I do believe that the work of cultural studies theorists becomes more and more important in exposing (making apparent), and then accounting for (making transparent) the biases coded in the technologies. We must demand equitable
instantiations of technology, seeking “strong objectivity” that seeks not to erase the human stain on technology, but to see either with it or around it, and to know when each is appropriate. Many chat rooms that are used in educational settings have a moderator whose job it is to shape the discussions, censoring according to prescribed rules. The limitations of what can and can not be said/learned/read within such an environment should be well documented. The elaboration of privacy policies and protection of identity should be well understood so as to prevent the unjust and possibly vicious exercise of power of one user over/to another. Consider the gender and class implications of a hypothetical Web resource called “Ask Dr. Math.” If Dr. Math is never shown to be a man or a woman, then will most children assume “he” is a man? The fact that “he” is a doctor could involve another set of assumptions that are socially, culturally, and economically coded in student stereotypes. Such stereotypes influence communication and conceivably the (un)willingness of students to communicate questions to Dr. Math. If a resume or cartoon picture was provided that challenged those assumptions (or at least made them explicit), then educators can begin to process with students the implications of what is appropriate to communicate with a “Dr.” Educators might point out that a group of graduate students, some male and some female, answer the questions for a fictional Dr. Math.

Technologies also must make the issue of authority a priority by incorporating some form of feedback mechanism. Many graphing calculators used in mathematics classrooms today will calculate the graph of a rational function, but will include spiky lines at “vertical asymptotes,” places where the function does not exist because of an
essential discontinuity (see Figure 4.1). Their calculator displays the malformed graph with the same authority that it would (correctly) display the graph of a simple linear function (a straight line with no breaks or jumps). The assumption is that the calculator is but one part of the student-instructor-calculator triad and that the student is, at each step and by instruction of the teacher, critically evaluating the representations the calculator is supplying.

![Figure 4.1: Calculator screen-shot (incorrectly) displaying asymptotes at x=-1 and x=3.](image)

The teacher may value a knowledge of rational functions that is consistent with the mathematics curriculum that says that the graph is incorrect as pictured. The calculator, on the other hand, places equal value on all output (it displays whatever it is asked to display within the confines of a prescribed interface). The student is left to negotiate the space in between two competing authorities – suggesting that the technology (and perhaps the teacher and student) is not able to critically self-evaluate within the exercise.
4.4.4 Criterion 4

To what extent does the technology inform the negotiation, creation, and acquisition of learning goals by the participants? To what extent is an effective form of assessment available with the technology?

Educators must understand that, to paraphrase Teddy Roosevelt, the price of technology’s great potential to allow students to negotiate learning goals is the responsibility of making sure that the technology is helping to achieve goals. An open-minded, though cautious accountability is in order – one that involves meaningful assessment of well-defined (though not necessarily prescribed) learning goals. In this new model of distributed authority, the student, for the purpose of assessment, is no longer only a “student-as-individual.” The student negotiates assessment authority and distributes authority for what counts as “official knowledge” or valuable knowledge with others in a networked fashion. When the student can no longer be assessed for having “internalized information,” how and what gets assessed? By whom? Education, as mentioned in the opening section of this chapter, maintains an accrediting function. Assessment is therefore integral to education. New technologies must support appropriate forms of assessment.

4.4.5 Criterion 5

In what ways and to what degree does the technology encourage the “intimate and organic union of... authority and individual freedom, and stability and change”? Technology has a significant impact on the social dynamics of the classroom. Dewey
was right when he argued that education should promote change on the one hand yet be valued for the stabilizing effects it can have (creating orderly communities, diplomatic solutions to war-tending problems, etc.). He recognized that authority must strike an agreeable balance with individual freedom. Technology should not allow an unchecked and unreasonable freedom at the expense of stability. The freedom that is sought in new technologies is the freedom to question, recognize, and enact productive authority.

4.4.6 Criterion 6

To what extent does the technology account for previous knowledge, situation, or habituation? Are mechanisms in place to aid in the authorization of the technology as a legitimate means of learning? The student may come to the new technology having been previously habituated to the fact that discussing homework with others is cheating. If the new technology is a WebQuest where students are to work together with others in the classroom and online, then are they made aware of the new rules of practice authorized within this community with this new technology? Authority involves communication and negotiation. If one party knows the terrain and does not support the other party's coming to know that terrain then negotiation is problematic. Authority also involves the valuation of certain forms of knowledge above others. This includes the valuation or legitimation of various ways of knowing above others. Mechanisms must be in place to help students critically evaluate the legitimacy of the technology as a means of learning.
4.4.7 Summary

The use of these criteria is a qualitative exercise in judgment that should occur within a dialogical context. This exercise about authority is ultimately an exercise in authority, involving the negotiation and recognition of what should count as valuable forms of knowledge. These criteria are intended to compose a framework for investigation. I will offer an example of its use in the next section when it is applied to two college calculus classes that introduce the computer as the primary instructional device in an effort to reconstruct traditional notions of authority and mathematical learning. Along the way, I will offer some useful constructs for thinking about technology and authority in relation to the student-teacher dynamic. In the final section, I return to the student-teacher model and discuss implications of this work on authority to the future of models for understanding this complicated relationship.

4.5 Calculus&Mathematica: Applying the Model, Testing the Criteria

This section uses the above criteria and model for authority and technology to explore the Calculus&Mathematica classroom mentioned in the second chapter. This section proceeds according to the six criteria outlined above. I assume that the reader is familiar with the description of the research site presented in chapter three.
4.5.1 Criterion 1

By whom is this technology constructed, and what degree of freedom do the users have to reauthor the technology?

The key electronic technologies are the hardware, software, and electronic text. The authors of the hardware are the engineers at Apple Computer Corporation and the technical support staff of the university who set up the lab, the tables, chairs, monitors, mice, and networking infrastructure. The software editors include the software engineers at Apple Computer and the programmers at Wolfram Research, Inc. who programmed Mathematica. Finally, the authors of the C&M text compose a team of mathematicians and graduate students from (mostly) two research universities in the Midwest. This list does not include those who, through interactions within the C&M classrooms with the instructors and textbook authors, shaped future versions of the text. They are authors in the sense of the model presented here, but due to limitations of space and for readability, I limit the list of authors to the “immediate” authors, thought of as akin to an “immediate family.”

The people mentioned above are able to perform their jobs because of having been successful in mathematics at or before the 1989 round of standards-based reform in mathematics. Software engineers, mathematicians, electrical engineers, computer scientists, and graduate students from those fields have all succeeded in mathematics or they wouldn't have the jobs they do. This is an important feature of this “team” of authors of the hardware, software, and text. Providing students an opportunity to “reauthor” the technology necessitates a shared language for articulating the ins-and-outs
of the technology. The “team” is fluent in the language of mathematics and computers.

Some important questions arise because of this: Is that fluency coded into the hardware in ways that physically block access of the students and instructors (both should be considered users) to reauthoring the technology? Is that fluency coded into the way that Mathematica issues commands, or the way that C&M describes mathematical phenomena?

The electronic notebooks form the basis of students' electronic homework and group work. Through copying, pasting, and making adjustments to the code they “reauthor” the textbook. Furthermore, the students, while reading through the introductory material (again in the form of an electronic Mathematica notebook), are encouraged to play with the numbers in the examples, recomputing the examples in a laboratory-minded exploration of the effects of certain constants and expressions.

According to the online documentation for C&M, “Not only are all calculations and plots alive and editable by students, the file containing the courseware is editable by students. Students are encouraged to insert their own thoughts, mathematics, and graphics as they create their own understanding of the concepts” (C&M, Role of Tech).

Each section of the text is subdivided into four sections. The “Basics” presents a conceptual background of the material, the “Tutorials” presents worked examples similar to the homework problems the students do in the “Give It a Try (GIAT)” section. The Basics, Tutorial, and GIAT sections are Mathematica notebooks. Also included in every section are “Literacy Sheets” containing problems that the students are expected to do using pencil-and-paper; the problems are similar to those encountered on tests and
quizzes that are also pencil-and-paper. Observations suggest that students often skimmed the basics and tutorials to try to go quickly to their homework which was often very intensive and time-consuming. Rarely did I observe students re-running examples from the basics and tutorials or adding their own notes to the text. Hence, while the calculations and plots may be “editable by students,” students were rarely observed doing so as part of a “discovery-oriented” reading of the Basics and Tutorials. There are many reasons that could explain this, including the time pressures and homework loads that pressured students into believing that spending time actively reading was less valuable than the time spent working on the homework. Based on conversations with one of the creators of C&M, and based on my observations of the types of questions that students asked, I am led to believe that the homework would have been easier and proceeded much quicker had the majority of the students carefully read and interacted with the Basics and Tutorials. Other explanatory reasons include that students' previous habituation has led them to not read mathematics texts before attempting problems. Also, to change the Mathematica notebooks requires a (very) modest understanding of the code and how to adapt it to produce new calculations and plots.

Despite an invitation to reauthor the examples and to adjust the provided text to provide homework solutions, the students were reluctant to do so. The “reauthoring” that exists along with the sort of “freedom” that Dewey discussed involves an exercise in (re)creating knowledge in a form that is personally meaningful. Most students I observed seemed to be driven to complete the assignments as soon as possible, leaving little time for experimentation while reading the Basics and Tutorials, and requiring a focus on
copying and pasting the example code, making as few changes and as few annotations as was necessary. This was, of course, not universal. Some students were fascinated by Mathematica and tried to gain a fluency in the coding language to feed their curiosity and interests. Such students were the exceptions. Moreover, it was possible to do well without reauthoring the text. Ann carefully read the computer text (and the printed copy at the same time) and asked questions of the instructor when she didn't understand. Through her very traditional and minimally interactive method of learning, Ann completed the course ranked at the top of the class.

Hence, the sort of reauthoring that took place most prominently (or that was encouraged by the instructors and courseware creators) was not tied to the freedom to recreate or reshape knowledge in personally meaningful ways. That the code was intended to be copied and pasted from an existing source, with a specific answer (or range of answers) in mind, suggests that there is still an “official knowledge,” written with an “official vocabulary” that all students were expected to appropriate in a fairly prescribed fashion. Part of this stems from an effort to de-emphasize the Mathematica code, making the course about the calculus concepts rather than about learning a new programming language. Students are expected to understand that a certain block of code produces a given result and to know how to make the changes necessary to solve any given problem. Another reason that there may be little room for reauthorization is that the concepts being learned remain fixed according to a fixed vocabulary and grammar. The language and grammar of calculus have been reworked by the authors of the C&M text, but students are not invited into that picture to change the mathematics of calculus in
any significant way. Of particular concern is the fact that students' proficiency using the computer to solve the problems may not transfer to similar uses in their careers given their reliance on having cut-and-paste code in the Tutorials.

The other forms of technology new to the calculus classroom are the hardware and the software. Students are not allowed to make any changes to the computer hardware since computers are not designed to accept hardware changes easily. Students are allowed to insert media into the computers (CD and floppy), usually to save work on the floppy and to read the computer text that is on the CD. It is conceivable that in the future students would be able to plug in a Pocket PC or their own tablet PC to have a more portable platform from which to transfer classwork and schoolwork. Furthermore, many students, despite using Mathematica which is one of the world's most powerful and versatile computational software packages, pull out calculators to handle basic arithmetic, suggesting the need for either a better or more familiar software interface or the ability for the computer to communicate with the calculator. Furthermore, I could imagine computers that easily accommodated personal physical differences, such as accepting different input devices (keyboards, mice, trackballs, data gloves, etc.). Currently the computers in the classrooms limit such changes as they probably will until it becomes financially justifiable (as felt through the dollar-vote encouragement of the purchasing agents of school technologies) to the computer makers to redesign the hardware.

The software, mainly Mathematica, was designed for use by computational scientists and mathematicians. Though Mathematica is used in many universities and colleges across the country, the fact that it is used so infrequently in many of the K-12
schools speaks to its audience (as limited by the structural features designed according to its vision of end users, and by its cost). While college students use *Mathematica*, it was designed with the professional mathematician in mind. The language it uses, as mentioned in chapter 3, is similar to Fortran or Lisp, and most professional computer programmers or mathematicians can learn the coding language quickly and efficiently. Hence, for that audience, *Mathematica* is easily reauthored to create packages with commands that are personally tailored to a given mathematician's uses. In the classroom, however, the code is often foreign to the students and represents an enormous obstacle for students to be able to reauthor *Mathematica* in any significant way. Without C&M as a template, issues of transferability arise.

The rest of the software used on the computer included mostly Web browsers such as *Internet Explorer* or *Netscape Navigator*. Students were encouraged to log on to a centralized Website containing assignments, syllabi, course announcements, and a chatroom space for the students to be able to communicate with their peers and instructors. Students often reauthored the intent of having these Web browsers available to them, using them to find Web games or to answer e-mail or to chat with students who were not part of the class. Web browsing was a technology with which the students seemed extremely comfortable. They were not, however using it in the context of the class, suggesting that the technology was not being reauthored, but rather retasked for purposes outside the scope of the class.

In general then, the technologies that distinguish the C&M classroom from other, more “traditional” classrooms, are designed and created by highly centralized teams of
professionals. While instructors are, in theory, able to make adjustments to the electronic text, none that I observed did. Students seemed the least able or free to make changes to the technologies, leading me to conclude that, even though small opportunities exist to change text examples, the C&M experience differs little from a more traditional classroom in terms of the degree of freedom afforded the student to make changes and to “reauthor” the technologies. Students were not able or willing to make significant changes to the text, the mathematics, the hardware, or the software.

4.5.2 Criterion 2

Appropriation of Diverse Forms of Knowledge, Regulation and Valuation of Knowledge

C&M courses are, at their heart, mathematics courses. One of the fundamental tenets of the C&M program is that mathematics has changed in the past fifty years to be much more qualitative in nature. Technology and the ability of computers to aid in visualization has led this shift. Despite this apparent change, the model of the objects of mathematical knowledge (theorems, fields, etc.) has changed little. Mathematical knowledge is approached and understood, but not changed in any way by being understood. This is as opposed to, say, history, which is changed through its retelling, its interpretation, and the need to continuously reshape it within the contexts of an ever-changing world. Hence mathematics has been taught from the epistemological perspective that there can not be diverse forms of mathematical knowledge of the same mathematical objects. Differences in understandings of mathematical knowledge reflect human imperfection rather than differential human interpretation. C&M, being a
mathematics course, shares this epistemology and, despite having changed the language by making it less formal than a traditional mathematics textbook, and despite having made mathematics learning more visual, interactive, and qualitative, and despite having rethought which parts of mathematics are to be most valued, it continues to subscribe to a Platonist point of view that the objects of mathematics exist in a state of partially revealed perfection. This is evident in their online documentation that states, “C&M presents calculus as a partially empirical laboratory activity with heavy emphasis on graphics. The first step is to determine what truth is; the second step is to explain it” (C&M, Visual Learning). The mathematics itself, especially what counts as “calculus,” cannot tolerate diversity in the sense of multiple, conflicting mathematics – meaning that this is not an option for the C&M class so long as it ascribes to a Platonic sense of what mathematics is.

Grant, for the moment, a Platonic view of mathematics (it’s very hard to find a working, professional mathematician who is not a Platonist at heart). If we allow for a single mathematics, then C&M allows a diversity of approaches to understanding the calculus. Traditional classrooms seem to be bimodal in terms of learning styles – spoken and written word. The C&M approach stresses visualization, reading, writing, and speaking – visualization being the strongest and most salient feature. Students are encouraged to meet deadlines for homework, tests, and group work, but on a day-to-day basis are allowed to work at a pace that suits them. This is confirmed in the online documentation as well as by students like Nessa Rose, “As long as you have done something with the material up until the quiz, you can do it at your own pace, you can do
it all the day before if you want to. A lot of it is up to you. I think the quizzes and the
due dates are really just cut-off points” (Nessa Rose #2, p. 9). Some students worked
individually reading the paper copy of the electronic text in their lap while having the
computer text open on the screen in front of them. Ann tended to work through the
Basics and Tutorials more thoroughly than her group mate, meaning that it often took her
more time to be ready to work on group assignments though she responsibly met all
deadlines. Other students skimmed the instructional sections and jumped straight into the
homework questions, having a window open for the homework on one side of the screen,
while on the other side a window containing the Tutorials. Their approach was one of
looking at the homework and then scanning the Tutorials for patterns that would suggest
a similar problem and therefore useful code to be copied from the Tutorials. Ann,
mentioned earlier, read through the computer text with a written copy of the computer
text in her lap. She needed the tangible comforts of the printed text as part of a careful
approach to learning the calculus. Hence C&M supported multiple approaches to
calculus knowledge, but not multiple, discrepant versions of calculus. This would
suggest that C&M is “evolutionary” rather than “revolutionary.”

Some of the C&M classes were encouraged to use the centralized online site
including the chat room. My observations suggest that students rarely if ever, used this to
interact or explore ideas with others in a bulletin board or chat room. Hence, despite the
hardware being fully networked, the students found little need to engage in a networked
approach to learning, seeking out ideas from places outside of class, or even to other
groups within class. Electronic discussions and forums were not well used in any classes

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I observed. Furthermore, only two of the classes used the centralized Website approach during the term being observed. Part of this difficulty may arise from the limits of the chat room software to support mathematical figures and text. Communication with other members of the class seemed to happen only as part of group work, and only within the confines of the lab. The need to have *Mathematica* present and the identification of the lab room and the electronic notebooks more specifically as the site of learning seemed to preempt any desire the students may have had to transport calculus learning to other spaces, virtual or material. Ann mentioned in an interview that she *does* try to talk with her friends in other (non-C&M) classes about differential equations and that those conversations are a valuable part of her education:

Me: Is that an important conversation? The conversations you have with others about O-Chem and ...

Ann: Yes. Actually it's quite interesting cause a lot of my friends are in the regular [differential equations class]... And it's funny cause I can look at their midterms and think, okay, this is easy. And they'll look at my midterm and be like, “are you kidding me?” It's just funny to see the difference. It's just easier to talk about, like if they have questions you can answer them. If you have questions on some stuff that they might have done that you couldn't do, they'll be able to answer them. Or even just in between. You're still generally able to talk, but I can't even talk to my friend [name omitted] about math and ask help cause she's in regular [differential equations]...

Hence, Ann had a desire to communicate about the mathematics outside of the classroom with other differential equations students who were not in the C&M program, but she felt that there was enough a difference that she was unable to talk with them. Given the small size of her class and her feelings of isolation within the class, the further feelings of isolation outside of the class point to communication problems and the ways that a lack of options for communicating with others about the mathematics, both inside and outside of the class, may lead to feelings of isolation.

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In summary, the C&M classroom technology was successful in encouraging
diverse approaches to the same mathematics. The end result for each student was
expected to be the same, despite the length of time or modes of understanding used to get
there. The networking features, having been poorly used (by students and instructors),
did not encourage the appropriation or sharing of a diversity of possibly disparate
information. The Platonic philosophy of mathematics that underlies almost all
mathematics instruction today orders and regulates the relative value of knowledge in reference to mathematics as the purest form of knowledge given its ties to logic and
symbolic representation. As Foucault reminds us in *The Order of Things*, the distinction
between “hard” and “soft” sciences is largely one of the given field's proximity to
mathematics. Physics is deemed a “harder” science than sociology because it is more
strongly tied developmentally to mathematics. Mathematics instruction generally, and in
particular C&M, being bound by a Platonic view of mathematical knowledge, establishes
a hierarchy of knowledge, with mathematics at the top (pyramid) or at the core (bullseye).
Beyond a “high status knowledge,” as a benchmark for other sciences, mathematics
seems to occupy the position of “highest status knowledge.” Students may carry this
perception as a construction of an insurmountable distance between a perceived “low
status understanding” and the “highest status knowledge.” This may dispirit the students
and lead to low motivation and confidence. The computer could be used as a means of
closing that distance, using its graphical and calculational efficiencies to build “I can do
this” bridges to high status knowledge.
Relating this back to the issue of the student-teacher dynamic, in this setting, mathematics will be embodied by the instructor and the computer text. The instructor is seen as more than just an “expert,” he is seen as possessing mathematics rather than as being knowledgeable “about” mathematics – he is the owner rather than the admirer. This view inscribes mathematics as a very personal mark upon bodies – fostering the mistaken belief in a biological disposition (or not) toward mathematics – that some people are able to do mathematics and others are not. In this case, mathematical practice involves an exclusive community of owners, making students the transient population, “borrowing,” “renting,” “sharing,” or even “stealing” mathematics for the time that they are in the mathematics class. Nessa Rose says that her instructor is different because “he's an incredibly intelligent man. He understands it very well and he explains it... he makes it seem really easy when he explains it and it's actually something you can do” (NR2, p2). Ann echoes these concerns with her instructor, saying that the instructor “knows it front to back... It leaves you very little room. He knows exactly what he's looking for, but you don't know” (Ann1, p8). Authority is tied in this sense to the perception of an exclusive and material ownership of mathematics. Furthermore, the language and syntax of mathematics and, in the C&M class, Mathematica, represents a further mark of exclusion since to “author” mathematics one has to be able to speak its language. This leaves students, if not “borrowing” or “stealing” the mathematics, in need of a translator so that they can participate meaningfully with mathematics.
4.5.3 Criterion 3

*Transparency of Technology*

The criteria list six categories in which to consider the transparencies of the technology: culture, society, economics, sexuality (and gender), race, and politics. As mentioned above, we can only make transparent what is exposed. The cultural, social, economic, sexual, racial, and political biases of computer, software, and mathematics have been repeatedly exposed (Damarin, 1998; Moses, 2001; Plant, 1997). To my knowledge, there have been no efforts to expose the ways in which the C&M courseware is situated according to the categories listed above.

The C&M courseware is written simultaneously in three languages to three different audiences. The language which makes C&M unique I call “informal explanatory (IE).” To get a sense of IE, consider the following explanation coming from a problem on linear modeling.

Bubba, a student at a large Midwestern university, is going to a party. He plans to be cool. More than that, though, he plans to drink plenty of beer at a party; after all he's got a reputation to uphold. But he is also worried about his driver's license. So he comes up with the scheme: He'll drink beer gradually at the rate of one 12-ounce beer every 10 minutes for the first hour; then he'll nurse one 12-ounce beer every half hour for the next two hours. After all this beer, he'll stop drinking and just sit around looking cool until he's sure his body fluid alcohol concentration is down to 0.5 grams/liter, a safe level for driving.

The only hitch is that Bubba can't figure out how long he has to wait from the time of his last beer until it's safe for him to drive, so he calls you up and asks you to figure it out for him.

Help out this poor devil. (C&M Growth, T.6.b)

The problem continues with an analysis of his body weight and how to figure out the concentration of alcohol in the body. Phrases like “At the end of the first three hours, Bubba will be stinko” (which appears later in the problem) don't usually appear in
calculus textbooks, signaling that this is a different and informal way of communicating the mathematics and solving problems. The creators of C&M call this language “conversational English” saying that “C&M is written the way actual American people talk to each other and not in the stilted prose associated with most conventional math texts” (FAQ, p8).

Figure 4.2 shows an example of the C&M notebook concerning the Mean Value Theorem. It is noteworthy for its division according to the three voices.
Just as in the “Bubba” example, this example demonstrates the informal explanatory (IE) style, talking about the horse racing, presenting the intuitive “If two horses start a race at the same point, then the faster horse is always ahead.” Immediately after that, labeled “Functions,” is an example of the second language used throughout the text, that of the more traditional, more recognizable formal explanatory style (FE) present in most textbooks. Here the function “(“ and “)” are replaced with Mathematica’s square brackets but the phrase “If f(a)=g(a) and f ′(x) > g′(x) for x > a, then f(x) > g(x) for x > a” is unmistakably the language of traditional calculus textbooks.

The text shifts from FE to Mathematica code (MC) at the marker B.1.a.i:

```mathematica
Clear[f,g,x];
f[x_]=x;
g[x_]=Sin[x];
Plot[{f[x],g[x]},{x,0,3},...
```

This code (MC) represents the third language in which the text is written. It is a code that demands syntactic and semantic precision in order to communicate instructions to the computer, in this case to produce a graph of the functions x and sin(x).

These three languages, IE, FE, and MC are intended for three different audiences. IE is supposed to be written the way “actual Americans talk” and seems therefore to be written with “just plain folks” (JPFs) (Lave & Wenger, 1991) in mind. FE targets a broader mathematical discourse, and participates in an effort to maintain contact and transferability with the more traditional calculus discourse. C&M graduates must still be able to articulate the Mean Value Theorem in functional terms and to calculate the limit
of the difference quotient when they leave the C&M program. FE would also seem to have would-be critics in mind who might object to IE as not part of an “officially sanctioned” means of communicating calculus. Finally, MC is a necessary interface between user and Mathematica, a highly structured and syntactically sensitive form of communication with a grammar that is only moderately decipherable if you have no familiarity with it. All three languages are needed to satisfy C&M’s goals of making calculus more relevant, more sophisticated, and more meaningful to students. Yet the trilinguality of the technology makes certain appeals to social, cultural, racial, ethnic, political and gendered norms. Also, the divergent ways in which the C&M text presents itself (in terms of written text) means that it is not situated contextually as a single locus, but rather is distributed throughout multiple loci within the space of culture, society, race, and so on. Different language uses have different effects according to gender and race, for example.

Culturally, the code (MC) in which C&M courseware is written suggests that C&M exists within a mathematico-technical culture that embraces the rules of logic, semantics, and syntax to solve problems of a technical nature. Yet the informal nature of IE belies more of a “frat-house cool,” that embraces humor and narrative in attempts to make the reader comfortable and amused. The use of FE exudes the mathematical culture of esoteric notation and strings of connected conditionals. Hence the C&M text exhibits at least three cultural influences.

Socially, C&M is a study of contradictions. The Macintoshes lined up column-by-column greet users with a security password screen that students must pass in order to
use the Apple Macintosh operating system. The lab is adorned with posters of colorful 3-D graphs and signs prohibiting the use of food or drink in the computer lab. Hence, while the explanatory language of C&M is informal, it exists alongside and within a social and cultural context that is primarily mathematico-technological and somewhat formal to most students enrolled in a freshman calculus class. While students feel this cultural duplicity, these feelings are not made an explicit part of the course. Nessa Rose thought it strange to see IE used in her text, saying “sentences like 'This number is squirrely as all get-out' or 'Look at that bastard grow!' about the exponential function: I was just like, 'well, that's pleasant!'” (Nessa Rose #1, p. 2) Still she had frustrations with the formality of the code and with the lack of explanation in some cases, saying,

NR: I really didn't understand for the first couple of days, the entire idea of having to access this particular folder to look at, you know, examples, this particular one to look at the work you have to do, and then in order to solve the problem, you had to cut and paste the code you need to get the plot. Which is so different from any code I've worked with...I'm just so used to traditional classrooms that this was really unexpected (Nessa Rose #1, p. 2).

In other words, student awareness of these issues indicated an exposure to the social and cultural biases of technologies, yet little was done to help students make this transparent or to help them handle the situation. It was, to many like Nessa Rose, “really unexpected.”

The setup of the computers so that the large CPUs form walls between the students encourages a social isolation that is usually overcome after the first couple of weeks of the course. Computers are physically designed for a single user, with one keyboard, one mouse, and a monitor that is best viewed head-on. The use of the computer texts, living within the space of the computer, was then, tied to the material
biases of the monitor and computer. Socially, then, the technologies encourage social isolation rather than communication and collaboration. The ways in which the technologies structure social interaction and speak to certain habits of learning and technology use is palpable in observations, yet there is nothing within the classes (in the form of discussions or activities) involving ways of handling social dynamics and technology’s roles in facilitating or hampering constructive dynamics. Somehow the students and teachers seemed to overcome the isolatory ergonomics of the technologies and to reach out to their group members to discuss problems. Instead of making transparent the social biases encoded in the technologies, the students and teachers seemed to ignore them. While the situation was “workable,” it seemed far from the excellence that might be achieved by actively dealing with the social biases of the technologies.

Economically and politically, the C&M textbooks had many example problems like charting the United States deficit according to the presidents in office at the time. The inescapable conclusion of one such exercise was that the deficit grew to enormous proportions during the presidency of Ronald Reagan from 1981 until 1989. Yet, these examples are “about politics” and “about economics.” C&M is also “political” and involved in the distribution of resources in economic ways. The economics in particular were made an issue of discussion in the classes. The students complained about the cost of the C&M CD-ROM, a product of Math Everywhere, Incorporated, which is a publishing/distribution business run by the creators of C&M. The class two instructor (also a C&M creator) detailed the $12,000 debt that the company had incurred in its first
three years and asked the students to be understanding of the cost of the CD-ROM (which was less than the cost of the comparable calculus textbook). He went on further to place on the blackboard the Web address of the university's policy on software piracy and acceptable use of the computing resources. He reminded them that it was “really scary what they will do to you – up to $10,000 in fines and they kick your butt outta here” if they were found copying the course's software. Even so, students in interviews knew of multiple burned copies of both the C&M courseware and Mathematica floating around the class for use at home. The grounded survey confirmed that students felt that it was illegal to make copies though 83% of the respondents indicated that “given the cost of Mathematica, they would install a 'burned' copy at home if one was available” (GS item 34). Hence the way in which the economics of C&M technologies were handled was monological, involving only a one-way discussion and a highly centralized imposition of authority by the instructor/creator.

Moreover, the political-economic concerns of the course were pronounced on the program's Website, detailing the ongoing struggle that the creator of the course faces to control enough resources to allow the course to operate. This includes instructors from the mathematics department, building space and funds for development and travel. The department displays a general distrust of calculus reform projects such as C&M and a few instructors who have initiated the reforms have operated within islands of reform rather than as part of the political mainland. The course two instructor has the added pressure of having to keep Math Everywhere, Inc. afloat. Still, there are signs that the instructor is having some success in his fight for resources. The computers in the lab are well-
supported and have been updated at least twice in the past 7 years. The class sizes have been kept reasonable (usually around thirty or fewer) in a department where a single section of calculus could have 120 students. While this facet of the C&M technology wasn't made explicit in the course (and therefore never made transparent), students were aware that C&M was a different calculus option that was supported by some of the engineering departments but not all. They were therefore conscious of the political nature of the course. The engineering advisors interviewed for this study confirmed this, recognizing that their recommendations differ from department to department. These recommendations were highly susceptible to political tides and the feelings of the department chairs towards C&M.

The racial and gendered biases inherent in the computer technologies and mathematical discourse were not made transparent in any way in the courses observed for the study. While these technologies have been repeatedly exposed for their gendered and racial biases, the course makes no efforts to address this. Pedagogically, group formation occurred without reference to sex or race. The text, as already mentioned, had a very male “frat house” tone to the IE. Also, as Nessa Rose pointed out, the text seemed gauged to a younger audience. Nessa Rose indicated that a middle-aged female friend of hers was taking another mathematics class and that she would worry about her being offended by IE in the C&M text. Moreover, the pedagogical push to manipulate the Mathematica code to reproduce multiple examples implied a techno-courage to just try things that is often difficult for older students who are afraid of “messing things up.”
Furthermore, C&M courseware emphasizes the power of rationality to solve problems and understand situations. Mathematics and calculus is portrayed as a tool of the intelligent but fun-loving member of the intelligensia. Knowledge of algebra makes even Bubba a more powerful person. Similarly, knowing how to use the computer to fit functions to data reveals truths about the politics of U.S. debt over the past fifty years. Hence “power” is granted to mathematical knowledge as a superior form of knowledge. “Smart” becomes a synonym for “powerful” in ways that Walkerdine recognized as the “rational dream (1987).” The politics of the C&M courseware also reflect the politics of the computer technologies in the classroom: Mathematica is constantly described as a “powerful” tool; the computer is able to compute quickly, efficiently, and powerfully. The student who masters C&M calculus is therefore constructed as a “more powerful” person who is better able to solve problems using the most valuable forms of knowledge. These politics embodied in C&M courses are certainly “exposed” but there is no room for discussion or for student/teacher probing of the assumptions behind the rational dream that is brought to life through C&M.

Very little of the set of biases was made transparent as part of the C&M course. The ways that transparency is accomplished is through the incorporation of a course component that explicitly deals with the new pedagogy, the new style of texts and problem solving, and the new computing technologies using a form of critical meta-reflection. The subject of mathematics and the technologies themselves ought to become a part of the discussion within C&M. A comparison of traditional math courses and their attendant expectations with those of C&M might have helped Nessa Rose early on to
avoid the surprise of the style of text and the means of interacting with the computer. Similarly, a more careful placement of peer groups (to be dealt with in a subsequent chapter) might have been a transparent way of dealing with race, gender, age, and tech-savvy issues that arise because of mathematics and the computer. Inviting students to model mathematically the profits and losses of a venture to publish their own mathematics textbook might have made the economic issue of the CD-ROM more meaningful to the students (and perhaps to the instructors). A problem that used the principles of optimization might have enabled students to model and redesign a classroom arrangement that used the space better, allowing better access for the instructor through the aisles, while getting rid of the CPU walls. In other words, there were steps that could have made the technologies part of the issue. C&M represents an effort to change mathematics instruction. Any model of change that views the changes as a top-down flow, from creator to instructor to student, is bound to run into problems with students' previous habituation in traditional mathematics instruction. The fact that the course has changed may become an impediment that works against the change. The lack of a critical meta-reflective component of the course leads to a failure to appreciate the productive potential of authority. Here the technologies have an unchecked hand in “authoring” student-instructor experience.
4.5.4 Criterion 4

Assessment and the Negotiation of Learning Goals by Participants

There are at least two levels on which to analyze the ways in which technology aided the negotiation of learning goals by students and teachers. First, there are the day-to-day details of the course including the scheduling of quizzes and tests, and second, there are the overall learning goals of the course often defined as either a set of skills/concepts the student should have mastered by the time they leave the course, or in terms of the curriculum or textbooks (often as the aggregate of all textbook sections discussed in the course).

The Day-to-day Negotiations

The intention of C&M courses, as read from the online documentation, is to allow students to work at their own pace, in learning modes that they prefer, and using a language more familiar to them than that usually employed in mathematics textbooks. The computer is used to support each of these three intentions, eliminating the lecture style that: presents material at one pace to all students, favors spoken and written words with very little visualization, and uses a polished mathematical language that hides the experimental ways in which mathematics is really practiced. Once lecture style “delivery” is eliminated, C&M favors a “Socratic Teaching Style” in which “questions are answered with more questions, rather than just telling the student the answer. By doing this, students are encouraged to discover concepts for themselves, rather than just accept what they are told” (C&M, Socratic Teaching). Students are “given...the
opportunity to work at a pace that is comfortable for them, thereby reducing the stress level and creating a more effective learning environment’’ (C&M, Learning Pace).

In my observations of the classes, test dates were not set at the beginning of the term, but rather set following certain sections of the textbook. Hence, tests were administered (to the whole class) when the class had completed a certain section of the text. This practice is consistent with the intention expressed in the online documentation to honor students' learning paces. Suma, a junior computer science major in class one, appreciated this, saying that “there is quite a bit of flexibility in the way that they set up the class” (Suma, 10/12/2000). She recognized the intention of the C&M course designers, saying that in a regular course, “you don't actually get to, on your own time, do it yourself, versus the computer where you're actually having to get a formula from another place, understand what growth rate is, figure out whether it's a variable, a constant growth rate, that type of thing... we're learning by ourselves” (Suma, 10/12/2000).

In class two, the instructor was asked by a student when the midterm would be. The instructor responded “We should probably set that. How 'bout a week from today?” The student responded “Okay” (Class Two, 10/26/2000). Midterms and major deadlines were scheduled similarly in both classes, often prompted by student questions about when the test would be.

Students in both classes negotiated the completion of their assignments outside of the guidelines established by the instructors. Both instructors discouraged the use of the “divide and conquer” approach to completing group assignments. The course one
instructor confronted Nessa Rose's group, saying “You guys are all working on
something different, what's going on? That's not a good idea to break them up.
Definitely a road to failure. It's best to work together but I'll leave that up to you”
(Course One, 10/26/2000). Students broke the group assignments into sections and
worked individually to complete each section and then met to “glue” their work together.
This represents one way in which students actively negotiated the completion of the
learning goals in ways that were not necessarily sanctioned by the instructors. The
computer made this easy since individual work could easily be cut-copied-pasted from
one file to another and give a final appearance of a single group author.

**Course-long Learning Goals**

The overall learning goals for each C&M course seem to be based on the section
numbers within the text. At the beginning of the term in both classes, the instructors gave
some indication (on syllabi or not) as to what the sections were that would be covered in
the course. There were no other subject-oriented learning goals explicitly stated by either
instructor at the beginning of the course. The only changes made to those goals occurred
when material from the end of the term wasn't covered due to time limitations, pacing, or
an over-ambitious agenda on the part of the instructor.

Students perceived some long-term learning goals that were not always apparent
to the instructors. For instance, Ann saw her differential equations course as being of
crucial importance to her intended career as a chemical engineer. In an interview with
Ann, she said that the tools that would be important to her field were *Excel, MathCAD,*
and to some extent MatLab. Mathematica was not perceived as being very useful to her. Moreover, she had serious concerns about the language being used and the ways that it differed from the language being used by her peers in a more traditional track. She had a vague image of the importance of differential equations to her career plans that included using the software tools she might use in her chosen field, and covering the material in ways that would allow her to communicate with others in her field. Hence, Ann had in mind a rough picture of who she should become and how she should get there as a result of the course. For her the course was part of her emergent identity as a chemical engineer and she therefore always judged the quality of the course according to the ways that it was completing her picture of herself as a chemical engineer. The instructor for her course recognized her abilities and quality performance judged by her grade, but may not have recognized the ways that Ann struggled with identity issues related to her perception of what the course meant for her. It is important to note that Ann's identity issues should have a lot to do with the learning goals of a course. Yet her learning goals are difficult to articulate in any general way. Moreover, her learning goals defy communication in terms of a set of chapters of the text or even a list of skills from which to demonstrate “mastery.” Open ended problems could present opportunities for the students to align the course content with their anticipated careers.
Assessment

Students were usually assessed using five methods: homework, group work, literacy sheets, quizzes, and tests. Literacy sheets, quizzes and tests were done with paper and pencil while homework and group work were done electronically in *Mathematica*. Of these, tests were seen as being the most important and most reflective forms of assessment. Suma said that “The computer work I’m getting feedback from, but that's not what I'm going to be tested, I'm going to be tested on it, but that's not physically what I'm going to be doing on the test” (Suma, 12/6/2000). My observations detected a sense of anxiety about the tests, that students knew that the tests would be entirely different from the electronic homework they were doing. They seemed to have palpable anxiety about the first test. This could be explained in several ways. First, the computer problems often involved large data sets and/or multiple steps. The applied nature of these problems meant that the numbers involved in fitting equations to data were often not “nice.” Students may have perceived that the tests would look a lot like the computer problems. Another possible explanation for this anxiety may have involved the lack of a set date for the test – students may have grown extra anxious given that they not only did not know what the test was going to look like, but they did not know when it would be and what information would be on it. A final possible explanation for this anxiety is that students are almost always a little more anxious about a first test with a new instructor. The anxiety may have been the same as in another course with a new instructor. Careful observations of a control group may have shed light on this hypothesis. In fact, the instructors mentioned on several occasions that the tests would look a lot like the quizzes
and literacy sheets, an explanation that may have been lost on some students amid the din of groups talking to each other in class.

The tests given in the two classes observed were markedly different in their approach to evaluation and assessment. The novice C&M instructor's tests closely resembled tests given in traditional classes, with problems that tended toward the procedural more than the conceptual. The veteran C&M instructor's tests resembled the literacy sheet questions, as promised, which tended to be more conceptual in nature and required more written English explanations than traditional tests. The novice instructor seemed to be suspicious of whether or not his C&M students would fare well relative to the C&M students and this could explain the style of his tests. The interview subjects, as mentioned above, devalued the meaningfulness of both the tests and the daily assignments, suggesting that the homework and quizzes don't look like the tests, and vice-versa. Moreover, it reminds us that students view tests above all other classroom tasks as the “ultimate assessment” of their knowledge. Hence students authorize examinations as the supreme measurement of their performance – the “ultimate authority,” if you will. The change in curriculum and pedagogy necessitates changes in assessment techniques. Unless assessment is integrated seamlessly with curriculum and pedagogy, students are likely to devalue and distrust their educational experiences as being a disconnected set of practices with shifting standards for what constitutes excellent performance.
New C&M professors should be educated by the C&M core participants about how assessment should/could reflect the principles embodied in the C&M curriculum/pedagogy. Faculty, too, assign authority to traditional assessment techniques and test questions per force of habit. Cultures within the department that resist change and reform may also hinder efforts to bring instructional assessment in line with the C&M philosophies.

**Summary**

Despite the apparent promise of a relaxed schedule designed to accommodate different learning paces, there is a tale told by Ann and one that points to several issues that educators must be aware of as they implement technology within the classroom. To begin with, Ann struggled with the course due to what she perceived as an absence of authority. Ann's model of authority is aligned with the traditional model in which there is an almost materialist presence or absence of authority, and authority is determined according to age and perceived knowledge/experience and articulated through imposed discipline and rules. Ann longed for her previous experiences with mathematics in which she was used to “having a teacher lead you through it, having something that if I have a question it will answer back” (Ann, 10/13/2000). She didn't mind deadlines, saying that “it is your own pace, but even though it is your own pace, I wish there were more deadlines that you knew you had to work towards. It's kind of hard like 'oh, we'll just have a midterm here,' I don't like that” (Ann, 11/30/2000).
Having an external authority act as the source of discipline was a preferred mode of learning and that was disrupted (intentionally) by the use of the computer in this class. Ann did not find the relaxed learning pace and flexible deadlines to be a source of support during her C&M course. Ann closely tied the issue of discipline to that of organization and structure, both of which she viewed as important to being able to successfully integrate the course into her personal life. At one point she described how the lack of a set test date made it difficult to commit to going out of town to visit her boyfriend since she did not know whether or not she would need to study over a weekend for a test. She added, ‘It's going to be hard if he's like, 'oh, we're going to have a midterm on Friday.' Well how are you going to plan your week around that? Especially if you work, and you're like well I don't have any midterms this week so I can take this double-shift Thursday night and not go to class Friday’ (Ann, 10/13/2000). The computer allowed for a well-intentioned relaxation of deadlines and structure that complicated Ann's personal life and extra-curricular work schedule. In her mind, this absence of a rigid timeline held her schedule hostage rather than freed it. It's easy to believe that students with more commitments could actually be disadvantaged under a laid-back pace as opposed to supported by it.

Still, Ann's case also offers insight into the inadequacy of traditional models of authority in light of technology. Ann seemed unwilling to confront the instructor about the timing of tests or to let the instructor know that she had other commitments she was trying to schedule that might conflict with studying for the tests. Her model of authority positioned her as without authority and the instructor with all of the authority. Under this
model, when the instructor sheds his authority, there is, as Ann believed, an absence of authority. To avoid a complete stalling of learning, as mentioned above, a better model might have energized Ann to recognize that authority was *made* by her actions as well as the actions of others rather than just *possessed*; that it was a process that involved communicating with the instructor and perhaps her peers, and that the computer allowed for a much more productive relationship whereby she could share her schedule and concerns by e-mail if she was uncomfortable confronting the instructor face-to-face.

Moreover, Ann's case highlights the ways in which the issue of quality or value enters into authority as a way of prioritizing or assigning greater value to certain activities and forms of knowledge at the expense of others. Ann's concerns about leaving town to visit her boyfriend arose only because she ranked her studies as of greater immediate importance than her boyfriend. It is not clear how the instructor would have responded had she shared this with him in an attempt to negotiate scheduling issues. For Ann, her traditional model of authority trapped her into a situation in which she simultaneously saw no authority in the class (measured in terms of structure and external discipline), yet also saw her self as reliant on the instructor's sole authority to set the schedule. The computer facilitated a pedagogy and educational philosophy that, without a change in the concept of authority and the student-teacher relationship, encouraged a paralysis of learning. This serves as a poignant reminder of the direct impacts theory (the model of authority) has on practice (the ability to teach/learn).

Students did manage to exercise authority in negotiating their assignments and the ways that they were being assessed by using the “divide and conquer” technique for
completing group (and sometimes individual) assignments. Even though this practice
was discouraged heavily, it was the principal way that I observed most groups completing
their assignments. Students definitely viewed this as productive in that it enabled them to
complete the lengthy assignments within a reasonable amount of time. This also was
probably an exercise in assigning value to different forms of assessment. There was
always a tension between pencil-and-paper assessment techniques (tests being seen as the
“truest” or most valuable form of assessment), and the electronic assessment techniques
(for which students spent the bulk of their time). Students were uneasy with the fact that
the part of the course they spent the most time on was not what they felt was most
important to their grade.

Homework, being of lesser perceived importance, presented less of an ethical
problem in terms of using learning practices that were discouraged by the instructor. Had
it been a test, I have little doubt that students would have been much more hesitant to use
techniques that were discouraged by the instructor (ones deemed “roads to failure” (Class
One, 9/26/2000)).

Finally, long-term learning goals ought to include more than just an outline of the
sections covered. Ann’s case demonstrates that some students may have strong feelings
about the importance of the course to their careers and lives more generally. It would be
much easier to encourage feelings of belonging and importance if the learning goals went
beyond a list of skills or chapters and included things like “at the end of this course, you
should have better means (and abilities) to solve problems dealing with multiple rates of
change” or “at the end of this course you will have more experience working with others
to solve problems and articulate solutions in a professional way – a skill that employers seek in hiring.” Ann had little encouragement in seeing the course as meaningful beyond *Mathematica* or Macs – things which, to her, were meaningless.

### 4.5.5 Criterion 5

*Authority v. Freedom*

Nessa Rose framed the discussion on authority and freedom well:

Nessa Rose: The timeline obviously gives you a lot of freedom. The amount of effort you're willing to put into understanding it is very free. I don't know, I mean, since everything is just given to you, you can either work to understand it or you can just accept it. That does give you some liberty there... I'm positive [the instructor] wouldn't object to you saying “why can't I use this method?” you know, and questioning what's already been given to you. I think he'd really enjoy that actually, but not so many people want to do it in this class I'd say. A lot of people are here for a GEC.

...  

Me: Are there limits to that freedom?  

Nessa Rose: There are certain rules of mathematics that you cannot break. The fact that we do have a quiz does put a damper on how much time you can take... (Nessa Rose, 12/1/2000).

Nessa Rose's quotation demonstrates the contradictions and tensions inherent to authority and freedom. “Everything is given to you” and “you can either work to understand it or you can just accept it” (emphasis added). In many ways, C&M's strongpoint is the ways in which it tries to bring authority/freedom and stability/change into the “organic union” that Dewey Speaks of (1936). The introduction of the computer here changes the ways in which we must think of the student-teacher dynamic. The computer disembodies the mathematical knowledge from the instructor (to a large extent)
and places it in the computer in the form of “information.” In this setting, knowledge arises from the interaction of the students, teacher(s), and computer when the information is contested, compromised, and comprehended. There is individual freedom within limits negotiated either locally (on a day-to-day basis within the class) or more globally (as a decision to enroll, or not, in the C&M class and to accept the terms of the syllabus).
The students in the C&M class co-author their understanding of mathematics with the instructors, and many students, like Nessa Rose, believed that they had a great deal of freedom in terms of the methods they could use to learn the mathematics. However, like Nessa Rose, they saw mathematics as something that was not changeable, as a static, non-contradicting body of received truths. They were simply free to receive that truth in a variety of ways of their own choosing. Others like Ann felt that they were forced to learn the material in ways other than the ones they preferred. All of the students I spoke with and observed felt that they were encouraged to ask questions of the instructors, a facet of the class that would suggest a great deal of authority on the part of the students. Moreover, the encouragement of questions made the class less tightly bound to a script as is usually the case in a lecture or lecture/recitation setting. Conversation, then, is seen as an exercise of freedom within the bounds established principally by the instructor.

The very existence of this course is rooted in the belief that changing the ways that calculus is taught (as well as adjusting its content) is necessary in light of political, demographic, and technological changes. Hence the organic union of stability and change that Dewey pairs with authority and freedom is, in this instance, weighted towards change, heavily in the case of instructional methods, and modestly in the case of adjustment to the content.
This call for change is reflected in the opening lines of a document generated by one of the creators of C&M to the mathematics department at his university:

Teaching in departments of Mathematics throughout the country is facing hard times. Faculty are unhappy with the students in classes at all levels, and students are openly critical of their courses and teachers.

There are probably as many reasons given for the current situation as there are people involved in the discussions. They range from low level of preparedness of students, through the ineffectiveness of individual teachers, to criticism of the techniques and methods, and even questions about the dedication of everybody involved: teachers and students. Without a doubt, there is some truth in each of the explanations presented. It is time to try to change the situation, both the perception and the reality. (Changing Teaching in the Math Department, p. 1)

There are several different areas one might look at in terms of gauging the changes represented by C&M. The most drastic changes, most of which already have been described, are in the pedagogies employed to teach calculus. The degree to which the computer is used and the attitudes toward removing the instructor from a position of “delivery” are also prominent signs of change. The creators of C&M claim to have “drop[ped] some of the parts of the standard courses that a former president of the American Mathematical Society call[ed] ‘inert’... [and] replace[d] the inert matter with fresh (mostly twentieth century) ideas” (FAQ, p. 7). The topics of the course have changed noticeably, such as an early focus on differential equations in the first calculus course and the removal of formal delta-epsilon proofs that served only the four percent of students intending to be mathematics majors. The computer allows the discussion of complex functions that might be too computationally intense for a traditional calculus class. It is important to note, though, that whereas the list of topics has changed, the “truths” of calculus remain the same. The changes might therefore be characterized as
the removal of certain materials and the addition of other topics that wouldn't traditionally be covered until later (if ever) in a student's mathematical career.

Other facets of the C&M experience are more difficult to assess in terms of change; for instance, the attitudes and expectations of the students and instructors. Some students were able to adapt to a new style of learning mathematics and this was marked by a change in their expectations of themselves and the instructor. The instructors varied so much (having met other instructors of C&M other than those I observed), that the attitudes and expectations of the instructors also varied yet were not within the scope of the observations I conducted, meaning that it is difficult to qualify the nature or extent of those changes (if any).

Another facet which merits scrutiny is the change in institutional support or resources. This was perhaps the most difficult facet to examine since I was not privy to the committee meetings, departmental e-mails, and other sites of contestation. My informal conversations with one of the creators of C&M suggested that keeping the C&M program afloat at the university required ongoing battles for funding and instructional resources. Based on these informal discussions, the level of support from the mathematics department could at best be described as tolerant.

In the presence of all of this change embodied in the C&M courses is a fair amount of stability. As an institution with accreditation responsibilities, C&M must participate in some form of a shared vision of what constitutes calculus proficiency. There is a certain core of topics that are seen in all calculus textbooks and courses that make up a foundation for what counts as calculus. For differential calculus, usually the
first calculus class, the ideas of instantaneous growth, the derivative, and the limit of the
difference quotient form a core of what first term calculus means. In as much as C&\textit{M}
has to participate in that shared vision, it contains the topics mentioned above, albeit in
possibly different forms from other curricula. Hence the curriculum has a topical core
that is stable and participates in a deferred authority involving a social consensus as to
what counts as calculus.

Moreover, as part of that process of accreditation, the instructor is positioned
institutionally as the individual responsible for certifying what counts as “success” and to
what extent (usually in the form of grades). The instructor is also seen as the individual
responsible for setting learning goals and administrating an environment that promotes
the attainment of those goals.

Hence, the instructor's role within C&\textit{M}, at the same time it has changed
pedagogically, remains a stable force for authorizing what counts as “official
knowledge.” The students also participate in this scenario, granting the instructor and the
institution that accrediting status in the hopes that being certified to know calculus fulfills
a later expectation (such as a satisfying job or a degree in a certain field).

Summary

The data taken from the C&\textit{M} classes and online documentation sheds light on
the need for a new model of authority. New communications and representations
technologies are reshaping the ways that knowledge is learned, authorized, and
communicated. The old society-individual binary is being rewritten into a yin and yang
in which the individual makes up one part of a collective intelligence not dissimilar from
that which Dewey speaks of (Dewey, 1936, IV 22) so that “society” is more than simply
a set of individuals bound by borders and language, but rather a web of distributed
knowledge(s). Authority too is distributed, though not among individuals, but through
them as a force for establishing relative values of certain forms and bodies of knowledge.
Student-teacher relationships are shifting from many-one to many-many because of and
alongside changes in technology.

In the C&M classes, the computers are used to demand limited authority
(authorship) on the part of the students. Whereas Nessa Rose demonstrates the palpable
tension between authority and freedom, between stability and change, signaling that the
C&M courses are introducing a form of change and freedom to students that they had not
yet seen in mathematics classes. Ann's tale, on the other hand, cautions us to the dangers
of an unharmonious union of authority and freedom and illustrates that there may be a
need for a centralized, rather than distributed, authority for issues of motivation and
discipline. This suggests that Dewey's “intimate and organic union of authority and
individual freedom” may be different for each person. This is not unreasonable given
issues of previous habituation (discussed in the next section), and personal preferences.
Moreover, it suggests that no matter how “life-like” technology gets, that the symbolic
embodiment of knowledge and authority in the instructor may be necessary to fine-tune
the union of authority and freedom.

The C&M data also detail how the accreditation feature of universities is tied to
issues of authority and how that impacts the student-teacher dynamic. The other side of
the accreditation coin is the issue of responsibility. It is unclear whether or not responsibility to others, for others, or for something, could ever be understood by or granted to a computer. Nevertheless, the glue that binds authority and freedom into an “intimate and organic union” is responsibility, and responsibility is, for the foreseeable future, a human trait. Instructors are responsible to the university for giving appropriate credit to students based on their performance. The issue that permeates this criteria is completing the sentences: “Instructors are responsible to the students for...” and harder yet “Students are responsible to themselves/the instructor/the university for...” The ways in which we complete these sentences strike at the heart of how the intimate and organic union of authority and freedom plays out. In the C&M classroom, there was an attempt to make the instructors responsible to the students for establishing an environment that allowed students to actively learn with peers and individually without central lectures. Also there is an attempt to make students responsible for learning actively by experimenting with examples and communicating mathematics with others. In many ways the intent of the C&M courses and the construction of the C&M curriculum is well suited toward encouraging freedom while disembodying authority, yet in other ways it sacrifices motivational and disciplinary aspects of authority that some, like Ann, find more freeing.
4.5.6 Criterion 6

Previous Habituation

When students enter the classroom, they bring their personal, familial, and cultural histories with them. In particular, they bring expectations of what happens in a mathematics classroom, what a mathematics teacher does, and what will be expected of them. It is not unusual to hear talk about teaching to the “whole” student, a philosophy that speaks to understanding students as located within a history and as possessing a set of habits and expectations formed largely from prior experience.

Changes in educational practices such as those in C&M often confront students' expectations about what a mathematics class is, what mathematics is, and how mathematics is taught. The instructor's perceived need to make changes to the class outweighs any students' need to keep things the same. The result is that students also must change their expectations, their ways of learning and behaving within a classroom, and, as we shall see, their identity as learners of mathematics.

Instructors are recognized as the final arbiters of change efforts. While I would argue that change should be motivated by and structured in conversation with students, it is nevertheless the case that instructors are granted license to author the nature of change for courses. As such, they shoulder the responsibility for making students aware of and comfortable with the changes. To do this, a) instructors must recognize that students have a prior history and habits that may need adjustment, b) students must be told of the changes and given support in making adjustments to those changes, c) instructors must offer a convincing argument that the changes are made in students’ best interests and are
therefore worth students' efforts to change longstanding habits and expectations, d) students must be offered the reflective space necessary to maintain a critical and open mind towards the changes, and e) instructors must recognize that some adjustment may be necessary on their part to change the course based on conversation and assessment with/of students. The following analysis will be structured according to these items.

**Recognition of Student History**

First, C&M as a curriculum and in its documentation recognizes that students have habits and expectations for what is done in a mathematics class. C&M owes its existence to a belief that those expectations and habits need to be changed to better support the learning of calculus.

The “Frequently Asked Questions” (FAQ) document includes the following question-answer couplet:

Q: Can students enter and be successful in C&M course after taking a traditional calculus course?

A: Yes. In fact at [name of university] about 50-60% of the students in each of these courses consist of newcomers. Newcomers are generally paired up with an experienced C&M student to help the newcomer transition into the class. (C&M : FAQ)

The documentation clearly recognizes that students make a transition even though the nature of that transition isn't discussed in the FAQ document. The differential equations instructor followed this strategy and, on the first day, grouped “newcomers” with “experienced” C&M students (which shouldn't be surprising given that he authored the FAQ document). In the case of the calculus I instructor, where every student was new to the experience, students were not divided into groups until the third day. The students
self-selected their groups and therefore no attention was paid to group composition according to experience with the computer, gender, race, or age. Even though the documentation clearly recognizes that a “transition” is necessary for most students, in practice, the instructor is given great latitude as to whether and how to help students transition into the changes represented in \( C&M \).

**Students Alerted to Changes**

Based on the data collected, students were well aware of the ways that \( C&M \) was different from other mathematics courses. Several of the items in the grounded survey demonstrate this awareness. Statistical summaries for several relevant items are listed below in Table 4.1. Numerical scores correspond to a 5-point Likert scale with 1 representing strong agreement and 5 representing strong disagreement with the statement.

It is evident from the questions listed above, that students perceived real differences in the \( C&M \) courses and furthermore that they seemed to favor those differences. This would suggest that these students were not overly frustrated by adjustments to the changes.

During observations of both classes, the students were told that it takes a few weeks to grow accustomed to the class. One of the undergraduate assistants in calculus I told the class about her own adjustment issues and encouraged them to persist, that things would improve. My own experiences teaching the course suggest that most (though not all) students will figure out how the class works and grow accustomed to new ways of
doing things within the first two to three weeks. This timeline for adjustment was
confirmed by the creator of the C&M courseware during informal conversations
throughout the observation period

<table>
<thead>
<tr>
<th>Statement</th>
<th>Median</th>
<th>Mean</th>
<th>St. Dev</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>This class is different from other math classes that I have taken</td>
<td>1</td>
<td>1.27</td>
<td>0.59</td>
<td>130</td>
</tr>
<tr>
<td>I have to do more self-motivation in this class than in other math classes.</td>
<td>2</td>
<td>2.57</td>
<td>1.17</td>
<td>129</td>
</tr>
<tr>
<td>I am a more active learner in this class versus more traditional math classes.</td>
<td>2</td>
<td>1.95</td>
<td>1.02</td>
<td>130</td>
</tr>
<tr>
<td>I feel comfortable working in groups in this class.</td>
<td>1</td>
<td>1.66</td>
<td>0.91</td>
<td>131</td>
</tr>
<tr>
<td>I learn more in this course than I would in a “traditional” course.</td>
<td>2</td>
<td>2.27</td>
<td>1.13</td>
<td>131</td>
</tr>
<tr>
<td>The Macintosh computers in the lab are easy to use.</td>
<td>3</td>
<td>3.22</td>
<td>1.40</td>
<td>130</td>
</tr>
<tr>
<td>Memorizing is important in this class.</td>
<td>3</td>
<td>3.04</td>
<td>1.10</td>
<td>131</td>
</tr>
<tr>
<td>Memorization is important in other math classes.</td>
<td>2</td>
<td>2.08</td>
<td>0.99</td>
<td>130</td>
</tr>
<tr>
<td>I have greater freedom to work at my own pace in this class versus other math classes.</td>
<td>2</td>
<td>2.29</td>
<td>1.20</td>
<td>130</td>
</tr>
<tr>
<td>This course is what I expected it to be.</td>
<td>2</td>
<td>2.62</td>
<td>1.14</td>
<td>130</td>
</tr>
</tbody>
</table>

Table 4.1: Student Awareness of Changes

Still, that students grow accustomed to the routines of the course doesn't speak to
how they do it. The only efforts I observed to acquaint students with the changes and to
support them in making those changes involved an introductory electronic notebook they
were supposed to read telling them about the changes, and the grouping (in some classes)
of experienced students with less experienced students. Aside from those efforts, students were expected to make the changes and adjustments on their own.

The irony is that C&M enacts a way of learning mathematics that is designed to be more in tune with students' preferred modes of learning (visually and in conversation with others) so that it would seem odd to observe the frustrations with getting used to the changes. This may speak to the strength of habits and expectations formed in and by previous years of mathematics courses. In the language of authority developed here, it may be that students have not been the primary authors of their mathematical experiences even as they have been the objects of authorized ways of knowing and learning mathematics.

The frustrations felt by Nessa Rose and Ann, some of which have been shared in earlier analysis, attest to the fact that adapting to the course takes considerable effort and open-mindedness and that those efforts need better support at the beginning of the course.

**Justifying Change**

Both the online documentation and the introductory notebook that is meant to help the student get acquainted to the courseware serve as sources that justify the changes inherent in C&M. Students generally seemed to accept these changes, as reflected by 75% of respondents indicating some form of agreement to the statement “I learn more in this course than I would in a 'traditional' course” or a 65% agreement with the statement “I have a greater freedom to work at my own pace in this class versus other math classes.” Also, 51% of the students agreed to some degree that “It is easier to learn
calculus on the computer than it would be to learn it in a lecture/recitation format.”

Moreover 71.9% of the respondents described the course as “A giant leap forward” as opposed to “like most others” or “a giant leap backward.”

Not all students were convinced by the courseware justifications. Ann was aware of the changes but did not always sense that they were having the desired affects. In the first interview, she described the mathematics in C&M as the same as other calculus course, but having been taught in the spirit of “Oh! Here's Euler's formula. Okay, that's great. What's it do for me?” (Ann 1, p. 14). She went on:

Me: So you don't think this is as applied as it claims to be?

Ann: No. No I don't think it is at all. They're like 'okay, there are examples; read them.' That's it.

So whereas the general consensus reflected by the survey suggested that students were convinced by the arguments made in favor of the changes, there is an important group of students who, like Ann, remain unconvinced.

Beyond the students, it is important to note that not all instructors were convinced by the courseware justifications. Many of my informal conversations with instructors other than the co-creator of C&M suggested that they remain skeptical about the claims made by the C&M documentation. Many of the instructors were young, some post-doctoral instructors, who saw C&M as a way of adding experience with reforms to their curriculum vitae or as a way of trying something new. They could generally be described as intrigued by the pedagogy and use of computers, but highly skeptical about the outcomes. Several expressed concerns that they weren't sure if the students were learning
the mathematics. This is an important perspective given that the paper-and-pencil tests could be a means for the instructor to test along much more traditional lines to assess whether or not the students were learning calculus as measured relative to the instructor's traditional sense of what counts for calculus. Several students, Suma included, expressed concerns that the tests were not very reflective of the language and problems done in their other work, both on the computer and in the form of the literacy sheets the students completed with pencil-and-paper. Furthermore, instructor skepticism speaks directly to issues of authority and could make instructors less likely to welcome negotiation and community authoring of the learning experience.

Reflective Space, Open Minds

When people adjust to change, they need the space to evaluate, understand, and reflect on those changes. Efforts to change the classroom environment radically must attend to the affective needs of students to provide the space necessary for adjustment. C&M instructors that I observed expressed recognition of the fact that it takes students a while to adjust, but provided little to nothing by way of activities or other things structured into the schedule to stimulate critical thinking about learning mathematics, about questioning habits, or about transforming expectations. Students do not always approach new pedagogical methods with an open mind (they are a lot like teachers, parents, administrators, and other humans that way). C&M could benefit by having activities built into the beginning of the courses that serve not only to get them working on and thinking about mathematics in new ways, but that also thinking explicitly about
how they learn mathematics and how that translates to action at home and in the classroom. Ann seemed the least open to change of any of my interview participants. She was not interested in doing mathematics (something she had been successful at in the past according to very traditional ways of learning and teaching) in new ways. The course was, for her, a necessary stepping stone on her career path, not an opportunity to change her established ways of learning. Suma and Nessa Rose were much more open to the changes though they struggled to varying degrees with how to make those changes and how to match their own expectations with those of the courseware and instructor.

**Instructor Willingness to Change**

Students are not the only parties that must be willing to make adjustments. Teachers teach students, not populations, and students have incredibly diverse needs that must be addressed by and for each class. Programs like C&M that are rooted in a desire to change things must also provide feedback loops that help to tune the curriculum, pedagogy, and course expectations to students’ learning preferences, personal lives, and professional goals. C&M seems to be collecting reactions to the course as evidenced by their online documentation, one section of which is devoted to the positive reports of former C&M students.

What is missing, however, is evidence that critical reactions to C&M are considered in making changes to the curriculum (by the co-creators of the courseware) or to the pedagogy (by the instructors). Beyond flexible scheduling of tests and quizzes, there was little evidence that the instructors made changes to the curriculum or pedagogy.
In fact observations of the class yielded numerous times when students asked for more introductory lectures – something that ran contrary to the philosophy of C&M. Though brief lectures sometimes occurred, introductory lectures were never observed.

4.6 Summary of the C&M Review

Part of the impetus to research issues of authority and to use C&M as a site for reflection has to do with my early sense that distributed or collective knowledge was what was being sought in the construction and implementation of the C&M curriculum. In fact, as the preceding analysis shows, while there are significant efforts made to decentralize parts of the learning process, institutional limitations make it difficult to decentralize certain aspects, even with the enabling power of the computer. In short, C&M calls into question aspects of authority and the student teacher relationship, even as it demonstrates limitations to significant change regarding authority and the negotiation of authorship of learning experiences.

The students' attempts to reauthor the technologies (and therefore the course) are limited by the highly centralized control over hardware and software issues. While opportunities exist to add notes to the electronic text and to make changes to the examples provided in the text, observations demonstrated few cases when students did this. Students may have been inclined to see the textbook as playing a certain role patterned on that of previous mathematics textbooks. Students and teachers must work together to exploit the potential of the technology to actively engage in rewriting mathematical learning. This could be done through multiple means such as asking
students to create a new notebook for each section that represents a distilled version of what the section was about and contains homework, questions, and notes. Having the text on a re-writable media (it is on a CD-ROM that may not be changed) would better enable students to make and save changes to the electronic text. Currently students have to save the text with changes in another location such as a network drive or removable media such as a floppy or Zip disk.

The mathematics of C&M is presented as “more qualitative” because of computing and visualization technologies but otherwise remains unchanged in content. As discussed before, this is most likely the result of the mathematical community's commitment to a Platonic philosophy of mathematics. Hence change is viewed as taking place according to the methods used to approach the mathematics and the computer is viewed as adding to the number of ways of making an approach. A commitment to Platonic ideals leads to this separation of content and ways of knowing. Once separated, content becomes sacred and unchangeable and ways of knowing mathematics (especially by non-professionals) becomes the sole target for change.

As content becomes sacred and unchanging, it also becomes a-cultural (or monocultural), a-social (mathematics is no longer the result of negotiation, but of discovery), anti-racial and gender-neutral (it participates in an ideal divorced from superficialities of human existence), and extra-economical (existing in the world of ideals rather than in the embodied world of materialities). Mathematics is seen as a core set of discovered (not created) truths that has imperfect human representations, and (sometimes) multiple approaches to knowing it. In the C&M classroom, it means that the mathematician
teaching the class can negotiate test dates and day-to-day matters, but the mathematics itself and what is considered important calculus is not up for debate. The computer has little effect here in de-centralizing power and the authorization of knowledge despite its great potential. The C&M text remains a gendered (frat-house male) and raced (white technocrat) representation of mathematics. It belies social, cultural, and economic preference given its use of computer as medium and its communication of what constitutes important problems given its use of “applied” examples.

The trilingual nature of the text (informal, formal, and machine) is a new technology of representation (relative to traditional univocal texts) but the cultural and social biases of this representation seem to make an assumption that the audience consists of young, academically-minded, techno-tolerant (if not techno-savvy) males.

The computer use allows a freedom of flexible scheduling that demands day-to-day negotiation of deadlines between the students and instructors. Long-term syllabus-type goals remain the province of the instructor (limited by community agreement as to what should count for calculus) and are not up for negotiation by students. Students furthermore have input into the deadlines and dates for tests and quizzes but have little influence over the content, style, and weight of those tests and quizzes. Homework and group work mimic the computer text and are completed on Mathematica using the language developed in the text. Literacy sheets focus on concepts from the Basics and Tutorials section of the text and are completed with pencils and paper. The tests and quizzes, however, are not always forms of assessment that reflected the work done by the students on the computer. As mentioned before, students of one instructor were tested
very traditionally to satisfy that instructor's desire to measure students' performances according to a scale more familiar to him. As the instructors don't have direct supervision by someone closely tied to the C&M project, there isn't any centralized control over testing styles.

The C&M courses make great strides in finding the “intimate and organic union” of authority and freedom, of stability and change, of which Dewey speaks though despite the technology, the instructor remains the one most responsible for managing that union. A poor support for student transition to the changes in C&M may have left students reluctant to seize opportunities to exercise freedom. Some students, like Ann, felt that too much freedom left the class without a motivating force or a source of discipline.

If there was a single unifying problem identifiable from this analysis, it was that students' transitions were not well supported. When they were not given the space for reflection needed to approach change with an open mind, they struggled to adapt to the changes in the quick-paced environment of learning calculus. They were reluctant to take advantage of opportunities because those opportunities were either unfamiliar or undisclosed. As such, the introduction of the computer did not have radical effects on the student-teacher relationship.
CHAPTER 5
DISCUSSION AND DIRECTION

5.1 Introduction

This chapter serves to summarize the previous chapters, connect the discussion on authority to other related topics and, by so doing, to problematize the model and generate further questions for future analysis. Rather than a “conclusion,” this chapter should be seen as a call for further discussion and refinement of the ideas set into motion by the dissertation.

The following sections will explore various facets of this model of authority including: its relationship to models of power, its relationship to “voice studies,” its relationship to traditional models of authority, and what its application to the example site (C&M) reveals about possibilities for changing educational practices.
5.2 The Traditional Model is Inadequate

Richard Sennett's 1980 book, Authority, offers a very complete picture of a modernist vision of “authority.” Recognizing that “everyone has some intuitive idea of what 'an authority' is, however difficult it may be to define” (p. 16), he offers several characterizations of authority as part of an effort to describe authority in terms of its perceivable effects on humans.

The most traditional element of his characterization centers on materialist perspective of authority, as “a bond between people who are unequal” (p. 10). Under this perspective, “an authority” possesses power whereas those “under” the authority are powerless. “Assurance, superior judgment, the ability to impose discipline, the capacity to inspire fear: these are the qualities of an authority” (p. 18).

Sennett recognizes the root “author” in authority, saying that “In English the root of authority is 'author'; the connotation is that authority involves something productive. Yet the word 'authoritarian' is used to describe a person or system which is repressive” (p. 18). The “author” seems lost in common perceptions of authority, and the meaning of the word when applied to humans has been identified with a disproportionate exercise of power of the authoritarian over the re/pressed. This vision of authority hinges on a materialist understanding of power, yet, as we shall see, it is not the same as power.

The defining element of the traditional or modernist sense of authority is its treatment in materialist terms. The co-development of technology and human social, cultural, economic, and political interaction has demonstrated the need to reconsider authority in terms other than as a quantity to be possessed. The data presented from the
C&M classroom confirms that authority involves a constant and fluid negotiation of authorship of the social text (the historical and multi-perspectived record of human action). The full capabilities of the computer as a network communications device were underused due to the situation of an “official knowledge” (one product of authority), using an official language specific to C&M, within the classroom. Students did not contest that knowledge or critically evaluate its representation (probably out of habits defined by previous years of mathematics education) and they were not encouraged to contest that knowledge or to use the capacity of the computers to draw in diverse perspectives as part of authoring their calculus knowledge in personally meaningful ways. In short, the students, instructors, and courseware creators approached the course with a highly centralized (read “owned”) view of authority. The gap between what was and what might have been possible was easily seen thanks to the introduction of the computer. In other instances we have all seen the computer being used to connect geographically distant people in the co-construction (or authoring) of knowledge. What was observed and heard in interviews was the modernist story of authority “within” a single person (instructor as the authority) exercised over the students. Despite efforts to decentralize that authority and to commit students to authoring their own learning of calculus, a complex of causes intervened. Technology becomes a foil against which we see prospects obstructed by comfortable habits and inadequate frameworks for understanding authority.
5.3 A New Model's Promise

Recent research on learning (Kirshner & Whitson, 1998; Davis, Samara, & Luce-Kaplery, 2000) and mathematical epistemology (Ernest, 1998) offer evidence that students must actively engage in meaningful tasks/activities for genuine learning (as opposed to short-term memorizing) to take place. The concept of “authoring” as the process and product that defines the student-teacher relationship is premised on both active engagement and personally meaningful activity. The effects of the traditional model of authority as a tool of control possessed by one party over another limits all chances of authentic, meaningful activity and stifles the individual freedom of expression (and reflection) as well as the development of supportive social bonds necessary for real “authorship” to take place.

When authority is recognized as an ongoing process that is generated by negotiation and communication by the participants of the group, the taken-for-granted status of teacher as the embodiment of subject and authority is lessened, making way for student entry into the conversation about what constitutes knowledge, which knowledge is important, and how knowledge can be learned. Moreover, when authority is seen as generated by all members of a group, rather than invested in a single person or subgroup, authority becomes productive rather than repressive. The power to author becomes a form of democratic participation.

The taken-for-granted nature of traditional models of authority is observed in the unquestioned beliefs that some have a prescribed “right” to author – prescribed by history, institution, or apathy. As authority involves negotiation among diverse people it
is never free from the politics of race, gender, economics, and culture. Honest negotiation of authority must work to contextualize interactions in the complex histories of inequity as articulated through these categories. Authority is about assigning value to some activities and some forms of knowledge over others. As knowledge is always local, in geography, space, and time, authority involves disputation, open-mindedness, and compromise as the principal tools for negotiating the relative value of competing bodies of knowledge and ways of knowing. Making this part of the operational framework of authority opens educational discourse to diverse ideas even as it makes central the issue of value and quality as a focus of that discourse.

There is, as they say, great peril in throwing out the baby with the bathwater. Regarding issues of authority, this caveat certainly rings true. As Dewey notes, there is a tension between authority and stability on the one hand, and individual freedom and change on the other. Traditional models of authority pit authority and individual freedom in an either/or war, leading to inaction and failure to compromise. Dewey recognized that what is needed is a harmonious blend of the two extremes (though he didn't say “balance”) so that the positive contributions of authority aren't lost to an anarchical embrace of individual freedom and so that the democratic recognition of the sovereignty of the individual isn't lost to the totalitarian authority. What Dewey failed to address was found in this investigation, which is that the “intimate and organic union” of authority and individual freedom is highly subjective and dependent on individual perspectives to shape and negotiate it.
Another characteristic of traditional models of authority is the view that authority is a very visible force, easily recognizable and very public. Such a view ignores the more covert ways that authority is institutionalized and made part of a process of self-regulation. Regarding technology, an Internet filter at a library's computer may be a very blatant instance of authority, yet more subtle is the way that the simple belief that we have that someone could be looking over our shoulders as we navigate the Internet causes us to change our behavior in some instances. The calculator that produces a graph for a student of algebra is assigned a degree of authority because of its computational power. Such authority isn't overt, a force that controls students visibly, yet its authority as a technology translates to the valuation of “High Status Knowledge” of whatever it may produce (however incomplete or incorrect it may be).

Having constructed a new model of authority that responds to changes made visible through/by classroom technologies, we are able to begin discussion of how to recognize and evaluate classroom efforts that use technology to affect the student-teacher dynamic. The six criteria developed in chapter four trace a path on which to ask questions and begin constructive dialogue about how to use technology to construct educational practices according to a more pragmatic model of authority. The criteria may be used as a qualitative evaluation of programs rather than as a quantitative checklist of the type one finds in an issue of Cosmo. This qualitative guide is seen as more supportive of the ongoing critical interrogations that ought to take place as part of efforts to construct better curriculum, pedagogy, and assessment at all levels of education.
Still, this model of authority and related criteria arise as a response to the growing presence of electronic technologies in classrooms. They are therefore situated historically and their usefulness may depend largely on when they are deployed. We can not imagine or predict what technologies or classrooms of the future may look like. Still, there is a degree of generality that inspires hope that the model and criteria possess some transferability to other locations and other times. While the model is explained in terms of modern classroom technologies, it is stated generally enough to allow some changes in the nature and uses of technology and still be relevant. For instance, it seems hard to imagine that a criterion that asks “to what extent a diversity of perspectives are made accessible by a technology” might become dated. Seeing authority as a process is, while a conceptual tool for seeing current practices, still conceptual to a degree that insulates it from the sways and pulls of small changes in educational practices. Hence the model and criteria for understanding the student-teacher relationship in terms of authority should have applicability to locations and times other than those studied here.

5.4 Calculus & Mathematica

One of the most rewarding observations of C&M was watching Nessa Rose's transformation over the course of the term. She began the course isolated and angry. My years of experience teaching post-secondary mathematics prepared me to accept the fact that Nessa Rose would likely drop the course by the fourth week. Instead, she became an important part of her group, opened up to people around her, and despite some thoughtful criticisms of the class, seemed to value the class as a meaningful learning experience.
Nessa Rose, as a psychology major with an interest in minoring in creative writing, didn't need to take calculus, yet she opted to not only complete Calculus I, but to enroll in Calculus II as well. Something in her experience convinced her that this was worthwhile.

Stories like Nessa Rose's don't happen every day in every mathematics class though, frankly, I wish they did. Ultimately Nessa Rose must be credited with her success in mathematics, her tenacity, and her open-mindedness toward challenges and new experiences. I am not certain whether or not Nessa Rose would have stuck with Calculus I and opted for the second term of calculus in a more traditional calculus classroom. Yet, in talking with her, I am led to believe that the things that she valued from the class are not yet to be found in other calculus classes at the university. She wanted to develop her group communication and leadership skills, her proficiency with communication in a technical field, and to find relevancy in the mathematics she was studying. I believe that she found all of these in C&M and that she may not have found those in the traditional classes.

At the heart of these differences in the C&M classes is the use of the computer to move the center of discussion away from the instructor and onto the students. This, I believe is the real strength of the C&M program, and what moves me to like the course so much. Yet at the same time that I genuinely respect the intent and delivery of the course, I also recognize, through personal experience, interviews with Nessa Rose, Ann, and Suma, and through the criteria developed in chapter four, that C&M is only a starting point for much more meaningful changes to the student-teacher authority equation.
Though I think it is often a shallow way of summarizing judgments, “grading” by category offers a useful, albeit highly subjective, way of viewing the criteria and beginning to see what possibilities exist for change. I will therefore give a list of the criterion, my grade (on an A, B, C, D, F) scale, and then a brief discussion. The grade reflects the degree to which the implementation of technology supports a democratic vision of authority relative to the focus of the criterion.

**Criterion 1: By whom is the technology constructed and what degree of freedom do the users have to reauthor the technology?**

*Grade: C*

While students are encouraged to re-author the C&M text, few did and it wasn't necessitated by the assessments outlined on the syllabus. Moreover, the syntactic demands of changing the *Mathematica* code may have dissuaded some from trying to make changes to the examples and to author comments. The hardware limitations also may have prevented students from reauthoring the courseware, since, for instance, the courseware was written on a fixed CD-ROM to which changes could not be saved. C&M deserves credit for emphasizing communication and for recognizing that students need to be able to reauthor (or co-author) their course record (the sum of actions and texts that arises as a “history” of their experiences in the course). Traditional calculus lectures would get an *F* in this category.
Criterion 2: To what extent does the technology allow for the appropriation or sharing of a great diversity of possibly disparate knowledge? To what extent does it order, organize, or regulate the relative value of different forms of knowledge?

Grade: D

These two questions would score an F in almost any traditional calculus course. Regarding the first question here, the courses use the computer to facilitate group work and group dialogue, so in that way C&M encourages the sharing of perspectives between group members. The communication aspects of the computer, including the use of the Internet and Web remains mostly unused. Instead of canned problems involving interesting data sets on the economy or populations, students could be encouraged to find their own data sets and explore problems of their choosing, with the final analysis including a presentation to the class. This might encourage the sharing of personally meaningful and diverse problems and solutions using calculus. Moreover, it may more closely correlate to the types of activities that students will engage after graduation.

As to the second question, C&M subscribes to a Platonic philosophy of mathematics, really the working philosophy of mathematics currently. As such, it presents a vision of what counts for calculus that can only diverge topically from other visions. The core of what constitutes calculus remains unchanged and unquestioned. It can be thought of as a unique narrative of the centuries-old story of calculus, changed in appearance slightly (as evidenced by its trilinguality), in application significantly, and in representation significantly. Calculus remains an
“unquestioned good” as part of the high status knowledge of mathematics and inherits a vision of order, and regulation for what counts for mathematics. While C&M gets only a D in this category, it is hard to find any curriculum that would score higher given the influence of Platonic philosophy on mathematics education.

**Criterion 3:** To what extent is the technology culturally, socially, economically, sexually, racially, and politically transparent? To what extent does the technology incorporate a mechanism for self-reflection?

**Grade: D**

As mentioned in chapter four, transparency first requires apparency. In C&M, the cultural, social, gendered, racial, and political aspects of the computer were not apparent to most students (if any). The economic aspects of C&M were made an issue by the class two instructor as part of an effort to justify the costs of the CD-ROM and to discourage students from making illegal copies of the courseware. Since most of these categories never became apparent issues for the students, they were never made transparent in the sense of recognizing the biases and working with, through, or around them.

**C&M** has a great untapped potential given the spirit of problem analysis and qualitative inquiry that guides much of the instruction in order to make the technology and its socio-cultural biases part of the course content.
The main tool that could be used by C&M is an expansion of its already strong emphasis on communication to include critical reflection by students about the course and about their experiences with the technology in the course.

Criterion 4: To what extent does the technology inform the negotiation, creation, and acquisition of learning goals by the participants? To what extent is an effective form of assessment available with the technology?

Grade: C–

Homework, quiz, and test deadlines were highly flexible relative to traditional courses and syllabi. Not all C&M students appreciated the flexible scheduling. Some, like Ann, felt that the flexibility led to an inability to plan ahead and to schedule their personal lives around the demands of their studies. One of the major goals of the courseware was to accommodate varying learning paces with flexible scheduling. The C&M courses observed for this study provided evidence that instructors supported flexible scheduling and accepted student input in setting the deadlines.

Students had little impact in negotiating the learning goals for the course. The course material established a preset body of work that students had to complete. As such, the courseware can be seen as a road map for the content-oriented learning goals for the courses. Other types of learning goals, such as communication skills, problem-solving ability were never discussed explicitly. Without discussion, there obviously was not any negotiation. Instructors fared a
little better, being granted the flexibility to decide the order and scope of the sections to be covered though for the most part the ideas about what should constitute a “calculus I” course or a “differential equations” course are well established through tradition.

The assessment regimen elaborated by the online documentation focuses mainly on text-based evaluation in the form of online individual and group homework in electronic notebooks, and pencil-and-paper work in the form of literacy “worksheets” and quizzes and tests. This scheme was devised to provide a “balanced” approach to making sure that students could demonstrate understanding individually and in groups, also both with and without the computer. In general, this strategy works well, though usual problems grading group work arise (does everyone get the same grade even if one person does all the work?). What is missing from the assessment regimen is a more qualitative factor that accounts for differentials in obstacles students must overcome because of having group members drop out, difficulties with access (including passwords), and other similar contingencies.

As in other categories, traditional calculus courses that rely overwhelmingly on tests as the final arbiter of evaluation would receive a failing grade for assessment. C&M does considerably better though it is well-poised to try new ways of engaging students in negotiations over the learning goals. Also, C&M makes a strong case that technology-based assessment can be meaningful and important in the mathematical sciences without overplaying its hand.
Criterion 5: In what ways and to what degree does the technology encourage the “intimate and organic union of... authority and individual freedom, and stability and change”? 

Grade: B

This is the category in which C&M did best. By recognizing that communication was central to learning and that decentralizing that communication stimulated active learning on the part of the students, C&M prescribes the “intimate and organic union of... authority and individual freedom” that Dewey describes. One of the lessons learned in this research involved recognizing that “intimate” and “organic” were judged differently by different students and instructors, suggesting that part of the social construction of authority and individual freedom requires finding ways of reaching compromises.

Ann was extremely upset with the “lack of authority” she perceived through the lack of external motivation and discipline whereas Nessa Rose and Suma appreciated that they were more involved in the learning process (the authoring process). Ann saw less freedom than a traditional course (most noticeably her freedom to schedule her personal life around the course and to work with software of her choosing) whereas Nessa Rose and Suma saw more freedom than in a traditional course.
Regarding stability and change, C&M found stability in its rootedness to a traditional view of what calculus is and what counts for legitimate forms of mathematical practice while it embraced change in the methods used to learn, communicate, and represent that mathematics.

**Criterion 6: To what extent does the technology account for previous knowledge, situation, or habituation? Are mechanisms in place to aid in the authorization of the technology as a legitimate means of learning?**

**Grade: D**

This is the one category where traditional courses are let off of the hook. Since traditional calculus courses operate similarly to high school mathematics courses at least to the degree that lecture is emphasized as the primary mode of learning, and since most courses use little or no technology to teach mathematics, there is little they must do to confront previous habituations of the students. Students come expecting to sit through lecture.

Students in C&M, on the other hand, must make a number of changes to their habits and expectations for a mathematics class. More daunting than adapting to the computer and *Mathematica* code is adapting to what the computer makes possible: learning mathematics in the absence of lectures, with the help of peers, and without the degree of external discipline and motivation found in other calculus classes.
The C&M instructors, for the most part, recognized that students took time to adapt to the changes and tried to acquaint them with those changes by either describing them on the first day or by pairing students who were new to C&M with students who had been through a C&M course before. Some instructors had students read through a *Mathematica* notebook meant to acquaint them to the details of the course. Still, after the first day or two, little was done to monitor the frustrations and progress students were making toward adapting to the new style of learning calculus. There is great promise revealed by C&M’s commitment to thinking about students’ learning. The innovation exemplified by C&M suggests that similar innovation could be brought to the task of helping students transition to the course more smoothly. Given the variety of instructors that teach the C&M courses, it is important that these innovations be made part of the curriculum so that novice C&M instructors could benefit from the wisdom of the courseware design team's ideas.

Some efforts were made to legitimize the computer and *Mathematica* as an important and powerful means of teaching calculus. Those efforts consisted mostly of “telling” rather than “showing” and relied on a “take my word for it” form of legitimization. As Ann's case shows, not all students saw *Mathematica* or the computer as the “right way” to teach the mathematics.
My observations and interviews with other students suggest that Ann's feelings on the matter were not the modal point of view, with students generally liking the computer and seeing the “power” of Mathematica to solve problems provided that they were able to construct Mathematica code.

5.5 Authority Amid the Swirl of Other Concepts

The second part of this chapter describes the relationship of this model of authority to other important concepts. By situating this model in relation to the other concepts, we gain a stronger understanding of authority and draw out some implications for this new model. In particular, authority must be understood in terms of power and knowledge, of society and culture, of politics and economics. Authority is used in many different ways as noun, verb, and adjective. The many masks of authority will be exposed in an effort to try to understand its use in each setting and to begin the project of reclaiming the word according to a better model of its use in action. Reclaiming the root “author” in “authority” seems to point to issues of agency and “voice.” Both of these ideas are explored in this second section as well. Finally, Dewey's issue of collective intelligence is given a re-reading relative to the model of authority developed here.
5.6 Authority's Masks

In popular usage, the term “authority” is deployed in several ways. Sometimes authority refers to people, sometimes to concepts, and sometimes to institutions. “The authorities” usually refers to some governing or policing body such as the police as in “if you don't move your vehicle I will summon the authorities,” or the NCAA as in “the authorities were consulted on the issue of eligibility.” “The authorities” can be read in both cases as enforcers. When authorities are consulted, as in “Dr. Dolittle is an authority on the behavior of two-headed animals,” the term refers to expertise, to people with great knowledge (“great” in the sense of magnitude and value). This sense is authorities as experts.

Institutions are similarly considered authorities as in “Public Works Authority” referring to a bureau granted the responsibility for maintaining a town's public utilities. This is not that different from the second usage above since in many ways the Public Works Authority acts as experts. Yet there is another dimension to this sense of authority that reflects the sense of authority as enforcement since in both cases authority is seen as endowed or granted by some other body. We might think of this sense of authority as incorporating license and duty.

In each case above, authority is treated as a possession. The experts possess authority; the Tennessee Valley Authority is granted authority, the police are given authority to carry out their duties. Yet authority is often conceived of abstracted from the human and institutional trappings of police and experts. The “amount of authority” to be given to a judge to decide a matter, or whether or not someone “has the authority” are
common usages of the term authority in very material terms. Authority is given, taken, shifted, or granted, but it always comes from somewhere and is allocated according to economic laws governing limited supply.

This dissertation is a reconception of the materialist concept of authority as well as an outline of a model of characteristics in chapter four to confront the materialist's authority that limits current educational practice and research. There are great pragmatic benefits to adopting a model of authority that sees authority as a social process embedded in cultural and ethical exchange. Technology is one way to make visible the limitations of old conceptions of authority and to create promising new directions for the effects of authority within educational practice.

But doing so requires understanding common usage of authority, and viewing those uses as opportunities to interrogate and change. While teachers often feel like enforcers, they probably would rather be encouragers. For that to happen, we need to change the ways we conceive of authority and to commit those changes to practice. While teachers are expert educators, a mathematics teacher at the K-12 level is probably not an expert mathematician. Similarly an English teacher may not be an expert on literature. Everyone stands to gain by recognizing teachers as resource and development experts who understand their students' educational abilities and know how to connect students to resources for developing their own knowledge based on a range of diverse authorities. Instead of an expert mathematician, the K-12 teacher becomes a participant in sharing authority with other professionals and inviting the expertise of others into the classroom to be shared and explored by the students. At the college level, the instructor
may indeed be an expert mathematician without a tremendous background in educational
development or processes. This has long been thought not as important at the college
level since the population is assumed to be an adult population. Still, the college
mathematics instructor has a diverse audience of students and she could stand to benefit
from inviting the educational and mathematical expertise of others into the classroom (via
the Internet or other means) to allow students more opportunities for constructing
personal meaning.

Finally, we must work to actively change our usage of the term “authority” to
divest its sense as “property” or even its constitution in limited supply. Authority may
exist by license and be enacted according to duty, but human influence in licensing and in
fulfilling duty must be considered a given in a democratic society. Democratic societies
depend on the belief that the individual can participate freely in contributing to the
direction and maintenance of that society. In this way, all institutional authorities are
“public works.”

Let's stop thinking of the teacher as an authority and begin to examine the
authority of teaching and the teacher's and student's roles in the construction of authority.
Let's shift from paradigms of enforcement to paradigms of enactment of principles of
self-discipline and consensual rule. Finally let's awaken the role of the individual as a
conscious participant in authoring the regulatory practices behind social institutions.
When we shift our thinking in these ways, we begin to reclaim the promises and
productive capacities of authority. This will be especially important as the distances
between cultures and people diminish in conjunction with improvements to technology.
5.7 Power, Knowledge, Freedom, and Voice

5.7.1 Power

A quick comparison of the model for authority advocated here and the description of Foucault’s “power” shows extreme similarities. One might easily ask “what is the difference?” There is good cause for the similarities between authority and power. As has already been mentioned, power, knowledge, and authority are very closely allied.

Richard Sennett has ably described the relationship between the concepts of power and authority, saying that “the bond of authority is built of images of strength and weakness; it is the emotional expression of power” (1980, p. 4). At first glance, his use of “emotional” is troubling in as much as a universality is suggested. In fact, Sennett is describing the bond of authority rather than authority itself. In the absence of a clear but useful conceptual definition of authority, we are forced to define it in terms of its effects. Sennett is suggesting that what binds us to authority, what makes it an important issue to us on a daily basis, is part of emotion; the desire for stability, the fear of change, the satisfaction of control.

Still, there are observable effects of authority besides the “emotional expression of power.” Power is often a part of intensely planned and consciously reasoned efforts. It is helpful to borrow Sennett's words, “Of authority it may be said in the most general way that it is an attempt to interpret the conditions of power, to give the conditions of control and influence a meaning by defining an image of strength” (p. 19, emphasis added). He continues, “to speak of authority as a process of interpreting power is to raise
the issue of how much the sentiments of authority lie in the eye of the beholder” (p. 20). Both of these quotations suggest that authority is an interpretation of power rather than power itself.

To understand the difference, consider that Shakespeare’s Romeo and Juliet has been interpreted multiple times in different settings. It has been performed as West Side Story in which two gangs struggle for control of streets while two “star crossed lovers” struggle to find expression of that love. This is a radically different interpretation than that of Shakespeare's time. Just as Romeo and Juliet is experienced only through its interpretation (on stage, film, or in the mind), so too authority is experienced only as the interpretation of the conditions of power. Authority is the visible part of the process of negotiating the social, cultural, political, and economic nexus that compose the conditions of power. Moreover, this act of interpretation (by and between groups of individuals) is intensely personal.

That authority is so personal (in the “eye of the beholder”) bodes well for a social science that recognizes authority as a useful construct while recognizing that authority, like truth and reality, is not modestly witnessed, but actively perceived. Authority involves interpretation, and interpretation is always a political act informed by the conditions in which the interpretation takes place. Saying that someone is “the authority” is not so accurate as to say that they are “an authority,” “a site of authority,” or “a participant in authority.” More useful, however, is to engage in dialogue to describe the conditions in which authority is negotiated.
This distinction between authority and power may be seen in Ann's comments about authority. Ann commented that there was no authority because the instructor was not disciplining or motivating the students. She also commented that the fact that the instructor had written the courseware meant that “he kn[ew] it front to back,” that he was the authority on the material. Here the conditions of power that Ann interprets are the conditions that position the instructor as the embodiment of a final condition of knowledge, an expert knower, and the student as the naïve, ignorant apprentice. Those “conditions” are the socially informed conditions involving gender, techno-scientific discourse, race, economics, culture, and politics. Ann's interpretation, rooted in her historical experiences with mathematics and schooling, lead her to interpret those conditions to believe that what is “authored” is her knowledge of differential equations, that she only “re-authors” her knowledge to be compared with the embodied knowledge of the instructor, and that authoring happens in the context of external motivation and discipline. Her view of power is less important than the way she interprets the context of power to structure limits on who, why, and how her mathematical knowledge is authored.

What seems to be a paradox for Ann, that there is simultaneously an authority (a person) and a lack of authority (a force) arises comfortably from the way she interprets the conditions of power within the classroom and based on previous circumstances. That Nessa Rose and Suma experienced authority very differently speaks to the very personal ways that authority is constructed. It is important to note as educators that the authority is a myth – teachers embody many very different representations of authority depending
on the students, parents, or others engaged in perceiving. Allowing for the fact that authority involves interpreting the conditions of power, then the student-teacher relationship can not be modeled procedurally or described in any detailed yet general way. Moreover, educators must understand that efforts to reform the classroom involve confronting and perhaps changing multiple perceptions and interpretations of the conditions of power that make up authority. This includes parents, administrators, teachers, students, and everyone else involved in the education of students.

5.72 Death of the Author/ Voice

The emphasis of the “author” in “authority” is not without conceptual complexities. The author remains a problematic feature of (post)modern times, conflated as it is with the concepts of individual expression, agency, and authenticity or voice. Roland Barthes (1977) first raised the issue of the “death of the author,” a theme picked up by Foucault (1979), to describe the loss of a source of originality of a given text. In other words, the author is not the originator of text (in most cases) but only a part of a more broadly structured discourse. The author is decentered. For Foucault, the act of writing (écriture), creates the author rather than the author creating writing.

Barthes claims that starting with the French Revolution the author is no longer at the center of the text, but is often pointed to as a pseudo-narrator of the text through certain grammatical signs like personal pronouns “I,” “we,” etc. Still, Foucault asserts that an “author function” can be identified that is a force that compels us to seek a person to identify with texts. Speeches, poems, novels, are forms of text that we need to see as
coming from someone – a form of attribution that situates a piece of text within a broader body of texts. For instance, Hamlet is Shakespeare's Hamlet so as to place it within the context of the other plays attributed to Shakespeare. This author function serves to assign the expectation of a certain style, level of quality, and historical context to a text. Consider the following thought experiment: suppose that Shakespeare's name was removed from Hamlet as author. Even as the words of the play would not have changed, the text would be received differently and judged differently – exhibiting the existence of the author function.

Not all texts have an author function. Texts such as fables, myths, one-liners, do not possess, nor do they seem to need, an author function. Scientific texts (and perhaps we might include mathematical texts) need not possess an author function according to Foucault. Scientific discourse is such that the author should be removed completely in order to claim a modernist objectivity. The use of blind juries in research journal publication is evidence of this.

Herein lies the connection with the present study. Let's begin by assuming that the highly discursive nature of mathematics learning, especially in the C&M classroom, involves the production of what might loosely be called a text. Student homework, questions, dialogue, all contribute to a personal volume that resembles a text record of their experiences learning mathematics. As such, issue of authorship arises, and in particular, following Foucault's question of “what is an author?”, we might also ask, “who is the author?” if one even exists. This involves the same issues as arise in discussions on “voice” in studies, and in particular in interpretivist/constructivist case
studies where a researcher attempts to hear and represent the voice of a participant with an eye toward authenticity (note the root “auth” again).

In the C&M classroom, as in other mathematics classrooms, the purported objectivity of mathematics is treasured as a sign of the universality of mathematical discourse. The exclusion of personal pronouns and the reliance on the language of logic are structural elements of text production in mathematics. Mathematical texts attempt to not create the author function within them. That Andrew Wiles, prover of Fermat's Last Theorem, wrote a text should not endow it with more truth than if another had written the same text. This has great importance in the mathematics classroom as the past few decades have sought to encourage students to find mathematical voice as they apply and adopt mathematical ways of thinking to their lives. The text record of their learning experiences is deemed deficient if, while attempting to provide evidence of mathematical achievement, invokes personal characteristics as means of elaborating or justifying the mathematics. In short, the student must be erased from the mathematical experience just as the death of the author moves the writer out of the way of the meanings communicated by the text.

Echoes of Dewey's calls for a union of individual freedom with authority ring loudly as we, as educators, seek to find ways to make students' mathematical experiences more personally relevant, personally meaningful, yet still reflective of the demonstrated power of mathematics to predict, categorize, and order experiences. Foucault's (and Barthes') argument that the author is dead, indeed even “killed by the writer,” seems to ring true within mathematical discourse where there is but one author of mathematical
texts. The author of mathematical texts is created by the texts themselves and he/she speaks in the genderless, bias-free language of logic and reason. Students may be writers who aspire to write this author into (re)existence, though without a massive disruption in mathematical discourse and the grammar of text production in mathematics, they can never be authors in the sense of projecting a personal voice into their mathematical writing.

It could be argued that keeping the human out of mathematics preserves the power of mathematics, just as it has been argued that scientific method is an attempt to remove the human from scientific inquiry. Yet with the death of the author, we may witness the birth of the critic and therein lies the potential for bringing the human (student) into personally meaningful experiences with mathematics without waiting for a revolutionary disruption in mathematical thinking and communication. We should invite students to apply their critical thinking talents to posing problems instead of just solving them, to constructing mathematical technologies rather than simply using them. The “intimate and organic union” of authority and individual freedom may be found in allowing students to engage in processes of understanding through questioning and criticizing.
Students might experience a more meaningful mathematics if instead of having as an end goal the removal of their voice from their mathematical text, we reawaken the margins of the voiceless text by filling it with student comments, questions, and criticisms. The bell curve is a standard feature of most statistics classes yet the controversy surrounding it (one which demands taking sides and engaging in criticism) rarely makes its way into the statistics classroom despite its relevance as a venue for finding meaning and import of the topic.

This strategy has as an advantage not having to wait for mathematics to change first so that mathematics educators can then seek to change in response. Mathematics education should treat mathematics with both respect and suspicion. Mathematics educators are in the advantageous position of being both inside and outside of mathematics discourse. As math users and confirmed recipients of university degrees in mathematics, we are insiders. Yet as educators, we are messengers, interpreters, and nurturers who, as guides, influence the path students might take to, through, or around mathematics. This is a special position occupied only by mathematics educators; not by mathematicians, not by parents, and not by the government or other administrative bodies. One way of strengthening the power of mathematics is to open it up to the voices of critique and reflection that students may bring to it. We must open-source mathematical culture and knowledge even as we make our personal experiences of mathematics central to our mathematical education.
5.73 Knowledge and Copyleft

Mathematics is often described as “a highly structured branch of knowledge” or as “logically precise form of communication” or even “the universal language” (where “universal” means “for all” and at the same time “of no one in particular.”) The grammar of mathematics has a precision and rigidity that can make difficult its use and appreciation. It is practiced consciously by few, and its boundaries are pushed by even fewer. Mathematics as a form of knowledge is “high status,” making it a highly exclusive branch of knowledge.

Students who study mathematics study an uncontested mathematics; a mathematics whose core assumptions, objects, and ways of knowing have remained unchanged for many centuries. Mathematical knowledge is controlled as if by copyright; it may be handed down from person to person only so long as it remains unchanged at its core (additions are only allowed at the boundaries of mathematical knowledge so long as they don’t change existing parts of the mathematical corpus). School mathematics is unchangeable and not open to critique or the injection of personal preference. It is a closed, copyrighted book. As long as the “source code” of mathematics, the mathematics of K-16 schooling, remains closed, the periphery of mathematics will remain the exclusive territory of a few homogeneous (mostly male) elite.

It is time to “open-source” or “copyleft” mathematics at its source. The “GNU’s Not Unix” or simply GNU Project (http://www.gnu.org/) has put forward a “copyleft” alternative to copyright. Under this arrangement, a document is copyrighted with the additional provisions that the document may be freely reproduced and redistributed, with
or without changes provided that the author and publisher receive credit and that all
future documents generated from this document are governed by a copyleft arrangement
as well. In this way the document is free in the sense of freedom and the writer of the
document retains credit for the original yet is absolved of responsibility for changes.

The body of mathematical knowledge is written as a large collection of texts.
School mathematics is furthermore written in the experiences of students and teachers
and informed by issues of authority. Central to this relationship and to authority is the
issue of control and interpretation of the conditions of power, specifically of the power of
authorship. We have much to learn from the example of copylefting. Consider a
copylefted school mathematics. Students must find an understanding of it as they
reinterpret it and reauthor portions of it to fit their experiences. We must not be
frightened as educators that they might reauthor mathematics “incorrectly,” for instance,
to say that the Pythagorean Theorem is incorrect. We have the responsibility as
educators to provide experiences that confront all parts of mathematics and its pragmatic
value so as to challenge student knowledge according to the wisdom of our previous
experiences and challenges in mathematics. This student may well learn that in two-
dimensions the Pythagorean Theorem is true, but that on a sphere, there are instances in
which the conclusion of the Pythagorean Theorem is indeed false. Such insights are the
treasured moments of educators and we must not shy away from allowing students to
author their own mathematical journey. At the same time, we must elevate our own
language to recognize instances like the example of the Pythagorean Theorem as valid
mathematical knowledge (albeit not consistent and not pragmatic). We must stop
speaking of confronting “mathematical beliefs” and start speaking of the process of knowing mathematics as a process of constant critical reflection. Adopting an open-source mentality toward a “copylefted” mathematics allows the processes of critical inquiry to work efficiently and productively by stimulating insight and innovation while recognizing personal meaning as a central part of mathematical knowledge.

As mentioned earlier, mathematics is taught as if it has a single anonymous author. Rather than stifling, this is productive since it provides for the opportunity for students to appropriate the mathematics, change it, challenge it, and reauthor it in experience. Mathematics' anonymous author retains credit as bourne out in its predictive and descriptive powers, while at the same time mathematics gains the inspiration (literally the “breathing in”) of personal critique and inquiry. Open-sourcing mathematics is a philosophy educators can adopt to promote a more meaningful and productive mathematics education for students (and of course for teachers). This is central to a new and productive vision of authority.

There is more to the idea of open-sourcing than simply the invitation to see, critique, and add to the “source.” The invitation is open to all and will only function efficiently if the critique and inquiry of the source is accepted by on a community scale. This involves connecting socially and culturally across distances and differences.

Once connected, the community must commit to functioning according to democratic principles of participation and self-rule. Such an organization has as its product a “collective intelligence.” The organization behaves in ways that are often chaotic, suggesting that complexity theory may offer insight into understanding the
potential for such a community. The next section concludes this study by offering a
vision for how this new model of authority could transform education.

5.8 Collective Intelligence and Complexity: Ways Forward

Part of breaking down the hierarchical perspectives on authority involves
recognizing that knowledge is held by a community of authors acting according to a
tenuous co-existence of individual freedom and socio-political influence. There is power
in social organization and communal rules for knowledge. Limitations of the human
mind mean that experts can not be generalists and vice-versa; embracing a collective
intelligence allows for a community of diverse experts acting through discourse to author
a collective knowledge.

Recent studies and trends in science suggest that complexity theories may be one
way of explaining how a body of knowledge comes to be within communities. What
arises from a body of knowledge is a “collective identity.” Brent Davis eloquently argues
this:

Just as my changing body is the locus of my personal identity – simultaneously setting me apart
from while situating me in the world – so our dynamic knowledge is the locus of our collective
identity – providing an integrity that distinguishes us from a background while placing us in
communion with that background. Our body of knowledge – that is, our established and mutable
patterns of acting – can thus be thought of as our collective self. As part of this body, we
constantly participate in its shaping, just as it serves to shape our own perceptions and identities

The individual actors act within the complex web of social relations and customs in ways
that are difficult to predict or model. Nevertheless, much as cells organize themselves
into organs in the human body, out of the chaotic swirls of discourse, knowledge arises.
Authority, once distributed, may find a better model through the lessons of complexity theory and create a better understanding of ways to confront, change, and celebrate new modes of enacting authority in the classroom. As educators we must be open to dialogue and to the pleasant victories brought about by not being afraid of taking risks and making mistakes.
BIBLIOGRAPHY


APPENDIX A

SAMPLE STUDENT CONSENT FORM

September 25, 2000

Dear student,

My name is Robert Klein and I am currently working on my Ph.D. in Mathematics Education in the School of Teaching and Learning. In my dissertation, I am interested in observing and analyzing the calculus instruction provided to students in your class. As part of my study, I am requesting your participation in three interviews regarding your experiences as a C&M student. These interviews should take only about 30 minutes each. All data collected will be kept in strictest confidence and quotations will be referred to according to a pseudonym of your choosing to further insure the maintenance of this confidence. The information you provide will contribute to a better understanding of mathematics instruction and possibly lead to stronger, more meaningful learning experiences in future mathematics courses.

Your participation is strictly voluntary and will in no way affect your grade in the class. If you choose not to participate at any time, you are free to do so by contacting me in any of the ways listed below. Thank you for your consideration of this request.

Sincerely,

Robert M. Klein <Advisor>
<Home Phone>
<Work Phone>
<e-mail address>

My signature below grants Robert Klein permission to use data collected from me during Autumn Term 2000. I understand that the data will be kept in the strictest confidence, that my participation is voluntary, and that I may withdraw from the study at any time by contacting the researcher as indicated above. I understand that I will receive a copy of this information letter for my records.

Signature
Social Security Number
APPENDIX B

SAMPLE LETTER FROM INSTRUCTOR

September 15, 2000

To Whom it May Concern:

I am the instructor for <math course>, a Calculus & Mathematica-based course offered fall term at the university. I have been consulting with Robert Klein about his dissertation project and support his conducting the proposed project in my courses during fall term, 2000. I understand that I can, at any time, retract my consent for observations of my classes.

Sincerely,

<Instructor>, Ph.D.
Instructor for <Math Course>, Fall Term
Department of Mathematics
APPENDIX C

SAMPLE INTERVIEW QUESTIONS FOR ROUND 1

- How would you say this class differs from other courses you take? How does this differ from other math courses you have taken?

- Do you feel like you are learning more in this course than in other courses? Why or why not?

- In what ways would you consider the course to be open for argument or possible dissenting opinion? In what ways is it closed to other views?

- Given that the text is computerized, along with much of your homework and group work, how have you made changes to the way you learn, if any, because of this? What would happen if you hadn't made those changes?

- There seems to be an emphasis on working with others. How have you made changes to the way you learn, if any, as a result? What would happen if you hadn't made those changes?

- The text seems to be written differently from other texts. If you perceive this difference, please describe it. How have you made changes to the way you learn, if any, as a result of this? What would happen if you hadn't made those changes?
APPENDIX D

SAMPLE INTERVIEW QUESTIONS FOR ROUND 2

- To what extent is difference constructed?
  - What does it mean to be you in this class?
    - Who is 'you' in this class?
    - How does this class affect your identity?
    - How does your identity affect this class?
  - Is there a difference between:
    - You and others?
    - You and the instructor?
    - You and the TA?
    - You and the computer?
    - You on one day versus another?
- To what extent is 'norming' occurring?
  - How do you judge how well you are doing?
  - How do others judge how well you are doing?
  - What does the instructor see when he sees you?
  - What does the instructor see when he sees you?
  - How are your expectations for this class constructed?
  - What is expected of you in this class?
  - Do you think you are seen relative to assumptions of who you are based on categorical descriptors such as woman, Caucasian, junior, etc?
  - **You mentioned in our last interview that you considered yourself to be above average in intelligence. How do you judge that?**
  - **You said your friend was “really smart.” How do you judge that?**
- To what extent is populational reasoning occurring?
  - Do you feel part of any group in this class? (Provide examples).
  - How does the instructor, the TA, the textbook, the computer (designers) view you in terms of?
  - To what extent does everyone else share the experience of this class?
  - What makes you stand out in this class?
- What is assumed to be universal? Local?
  - What does this course in each of its facets (learning styles, expectations, experiences, applicability of this mathematics, etc.) assume to be universal?
  - What do you think is assumed to be particular?
- To what extent is this math “ordered”?
  - What is meant when someone says that something is ordered, as in structured, organized, etc.?
  - Is math “ordered”?
- To what extent is the course “ordered”?
  - To what extent is this course “ordered”?

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• How are assumptions about order built in to this course?
• Do you like “order”?
  • Would you say that you like and appreciate this kind of order?
  • Always? When? When not?
  • Do you like rules? Established methods?
• Ditto the above for discipline.
• Is there greater or lesser “freedom” in this course than others?
  • To what degree is there more or less “freedom” in this course?
  • What do you think is meant by freedom?
• How is that freedom administered?
  • Is that freedom limited? How?
  • Are there established boundaries to that freedom?
  • Is that freedom applicable to everyone?
• How is what happens now NOT an inevitable consequence of it's history?
  • Are there any things that happen in this course that are consequences that are unexpected or unforeseen by those who create this course?
  • Who dictates what goes on in this classroom?
  • Each day you come to class, what do you expect from that new day?
  • Where did this course come from?
  • Years from now, what could educators say they learned from this?
• Describe this class to another student so that they wouldn't have any questions about what it was like (from a student perspective) What happens? (get at a description of C&M as a social technology)
• Describe this class to another student so that they wouldn't have any questions about what it was like (from a student perspective). What happens? (get at a description of C&M as a social technology)
Thank you for taking the time to answer this brief survey. Your honest answers will contribute to expanding what is known about mathematics education and will also help me in my pursuit to capture a Ph.D. Your participation is strictly voluntary and should you choose to complete this survey, I assure you that responses will never be identified in any way with you as an individual. Therefore, please do not place your name, social security number, birth date, etc. on this form. I will be the only person who sees these forms – they will never be seen by your instructor, TA, or anyone associated with your grade. This research project has been cleared by the Office of Research’s Human Subjects Review Process. Thanks again! Bob Klein. <e-mail> <home phone>.

1. Sex: Male Female

2. Rank: Freshman Sophomore Junior Senior Other

3. Class: 151C 152C 153C 254C 255C 415C

4. Major: ____________________________________

5. Anticipated Career Field (eg. engineer): ____________________________________

6. Why did you choose the C course (as opposed to “regular” calculus)?

__________________________________________________________________

7. Is this the first time you’ve had this ‘C&M’ class? Yes No

7a. Is this the first time you’ve taken any ‘C&M’ class? Yes No

8. Please list all math classes taken for three or more weeks at the college level:

__________________________________________________________________

For the following statements, please indicate your level of agreement with these statements by circling the appropriate number from 1=Strongly Agree to 5=Strongly Disagree.
<p>| | | | | | |</p>
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<tbody>
<tr>
<td>9.</td>
<td>I have heard that the ‘C&amp;M’ courses are easier than ‘traditional’ calculus courses.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>10.</td>
<td>In my experience, the ‘C&amp;M’ courses are easier than ‘traditional’ calculus courses.</td>
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<tr>
<td>11.</td>
<td>I am able to get the help that I need in this class.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
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<tr>
<td>12.</td>
<td>I learn less in this class than I would in a ‘traditional’ class.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>13.</td>
<td>I feel comfortable working in groups in this class.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>14.</td>
<td>In my group we divide the problems between us so that everyone works on a part of the group work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>15.</td>
<td>The computer tasks are well suited for group work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>16.</td>
<td>It is difficult for the group to work around the computer.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
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<tr>
<td>17.</td>
<td>The ability to work in groups is important in my anticipated career.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>18.</td>
<td>The layout of the room is well suited for group activity.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>19.</td>
<td>I have to do more self-motivation in this class than in other math classes I take.</td>
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<td>2</td>
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<tr>
<td>20.</td>
<td>I work in the computer lab outside of classtime.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>21.</td>
<td>I am a more active learner in this class versus more traditional math classes.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>22.</td>
<td>The instructor doesn’t participate in an adequate way in this class.</td>
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<tr>
<td>23.</td>
<td>Using computers will be necessary in my anticipated career field.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>24.</td>
<td>Mathematica could be helpful in my anticipated career field.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>25.</td>
<td>If I could drop this course, I would.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>26.</td>
<td>I think that I am doing well in this class.</td>
<td>1</td>
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<td>27.</td>
<td>I feel comfortable asking questions in this class.</td>
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<td>28.</td>
<td>Grades are my principle way to judge how well I am doing in this class.</td>
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<td>29.</td>
<td>The TA is helpful.</td>
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<td>30.</td>
<td>I am different from most people in this class.</td>
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<td>31.</td>
<td>I understand the relaxed style of language in the computer text better than the styles used in traditional math textbooks.</td>
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<td>32.</td>
<td>They try to make the computer take over the role of the instructor.</td>
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<tr>
<td>33.</td>
<td>It is possible to do well in this class without having a copy of Mathematica at home.</td>
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<tr>
<td>33a.</td>
<td>I would do better in this class if I had a copy of Mathematica at home.</td>
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<tr>
<td>34.</td>
<td>Given the cost of Mathematica, I would install a “burned” copy at home if one was available.</td>
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<tr>
<td>34a.</td>
<td>Given the cost of the courseware, I would use a “burned” copy if one was available.</td>
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<tr>
<td>34b.</td>
<td>I have or know someone who has a “burned” copy of either the courseware or Mathematica.</td>
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<tr>
<td>34c.</td>
<td>I believe that it is my right to copy Mathematica or the courseware.</td>
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<td>35.</td>
<td>I am treated differently than others in this class because of my race/gender/class or other personal attributes.</td>
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<td>36.</td>
<td>We are doing real mathematics in this class.</td>
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<td>37.</td>
<td>I learn more in this course than I would in a “traditional” course.</td>
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<td>38.</td>
<td>This mathematics is important.</td>
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<tr>
<td>39.</td>
<td>I get adequate feedback on my performance in this class.</td>
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<tr>
<td>40.</td>
<td>This mathematics is relevant to my future plans.</td>
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</tbody>
</table>
41. The lab is a comfortable space.

42. I feel comfortable making mistakes in this class.

43. The math that I learn in this class applies to the real world.

44. It is important to understand *Mathematica* code to do well in this class.

45. Women are better than men at subjects like English and History.

46. Making mistakes is part of the learning process in this class.

47. The Macintosh computers in the lab are easy to use.

48. This class is different than other math classes that I have taken.

49. I have used calculators in my previous high school or college math classes.

50. I prefer calculators to computers in math class.

51. Memorizing is important in this class.

52. The computer does most of the thinking in this class.

53. Courses in the future will look a lot like this class.

54. Memorization is important in other math classes.

55. This class has a “laid back” feeling.

56. I consider my self to truly be gaining proficiency in calculus.

57. The instructor sees me for who I am in this course.

58. Mathematics is a very structured branch of knowledge.

59. The calculus I learn is organized so that new material builds on previous material.

60. I am seen as just one student among many in this class.
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<tbody>
<tr>
<td><strong>61.</strong> I have greater freedom to work at my own pace in this class versus other math classes.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>62.</strong> Men are better at math than women.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>63.</strong> Time is highly organized and structured in this class.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
</tr>
<tr>
<td><strong>64.</strong> This course is what I expected it to be.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>65.</strong> I like a laid back environment in class.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
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<tr>
<td><strong>66.</strong> I would not recommend this course to others.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
</tr>
<tr>
<td><strong>67.</strong> I wish that time was more structured in this class.</td>
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<td>5</td>
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<tr>
<td><strong>68.</strong> My grade in this class seems to be a fair reflection of my understanding of the material.</td>
<td>1</td>
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<td>5</td>
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<tr>
<td><strong>69.</strong> I learn a lot from my group.</td>
<td>1</td>
<td>2</td>
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<tr>
<td><strong>70.</strong> I have lost work due to computer crashes.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
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<tr>
<td><strong>71.</strong> Math frustrates me.</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
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<tr>
<td><strong>72.</strong> Everyone can learn in this class.</td>
<td>1</td>
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</tr>
<tr>
<td><strong>73.</strong> It is easier to learn calculus on the computer than it would be to learn it in a lecture/recitation format.</td>
<td>1</td>
<td>2</td>
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<tr>
<td><strong>74.</strong> I learn a lot from the computer.</td>
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</tr>
<tr>
<td><strong>75.</strong> The computer frustrates me.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
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<tr>
<td><strong>76.</strong> Mathematics as a field of knowledge builds on itself.</td>
<td>1</td>
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<tr>
<td><strong>77.</strong> I learn a lot from the instructor in this course.</td>
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<tr>
<td><strong>78.</strong> I spent too much money on the text, CD, etc. for this course.</td>
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<td>5</td>
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<tr>
<td><strong>79.</strong> Men do better than women in math classes.</td>
<td>1</td>
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<tr>
<td><strong>80.</strong> I am a visual learner.</td>
<td>1</td>
<td>2</td>
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<td>5</td>
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<tr>
<td><strong>81.</strong> Everyone else seems to be having the same experience in this class as me.</td>
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<tr>
<td>Statement</td>
<td>Strongly Agree</td>
<td>Strongly Disagree</td>
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<td>--------------------------------------------------------------------------</td>
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<tr>
<td>82. I learn a lot from the TA in this course.</td>
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<td>83. Math and computers go together well.</td>
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<td>84. I would change groups if I could.</td>
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<td>85. The money I spent on this course was worth it.</td>
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<td>86. In general, I learn better in lectures than by reading the text.</td>
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<tr>
<td>87. I learn a lot from myself in this course.</td>
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<td>88. The material on the test reflects the material covered in the lit sheets/homework/Basics/Tutorials.</td>
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<td>89. This class would be very different with a different instructor.</td>
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<tr>
<td>90. People who like math like computers.</td>
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<tr>
<td>91. I would work alone in this class if I could.</td>
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<tr>
<td>92. People who like computers like math.</td>
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<tr>
<td>93. <em>Mathematica</em> is easy to use.</td>
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<tr>
<td>94. In general, this class is:</td>
<td>A giant leap forward</td>
<td>A giant leap backward</td>
<td>Like most others</td>
<td></td>
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</tr>
</tbody>
</table>

Please feel free to add any additional comments you might have to the bottom or back of this page.

Thanks again for your participation!