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REFLECTIONS ON TEACHING A MATHEMATICS EDUCATION COURSE

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Curriculum and Instruction

by
Sarah Elizabeth Smitherman
B.S., Texas A&M University at College Station, 1995
M.A., Louisiana State University, 2002
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For all of the teachers in this world,
whether formally or informally,
you are my inspiration, my audience,
and my hope for the future

For Bill Doll and Donna Trueit,
your passion and relentless pursuits
challenge me, encourage me, and
enlighten me

and

For my sweetheart, whose love and support
sustain me still

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Most of all, I wish to acknowledge my sweetheart, Chris Pratt. More than words. I love you.

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Abstract

Teaching and learning involve reflexive actions and should be chosen thoughtfully and deliberately, not because someone has decided "what works." In this study, I examine how complex conversations might offer pedagogical and theoretical (re)considerations in a teacher education course on mathematics. The term "math methods" is a doubly weighted phrase, for both *mathematics* and *methods* connote particular ideologies prevalent in current educational rhetoric. In order to unpack the impact of these words, I engage in research based on inquiry, historical analysis, and personal reflections, all of which I use in an eclectic, thoughtful, and explorative manner.

The two main research questions I will explore in this dissertation involve effort by "teacher" and "student" in which both are learners, knowers and participants. The first question is how can complex conversations—those involving multiple perspectives—aid pre-service teachers in becoming reflective practitioners, effective professionals, and inquiring pedagogues? Specifically, teaching mathematics as a relational activity—in which a hermeneutical perspective is crucial—brings forth epistemological questions and issues. The historical situatedness of teacher education and mathematics education become relevant with respect to current epistemological perspectives of teachers and researchers, and these influences are examined in the context of pre-service teachers' positionalities. The second question involves an examination of how I am transformed as I experience and reflect on participation in these complex conversations. While engaged as an instructor, I am simultaneously influenced by research in complexity theory, curriculum theory, and teacher education.

In complex conversations, we can find possibilities for teaching and learning, even potential ways of being that we do not yet know. Complex conversations encourage a different

form of interaction, a different way of imagining the world—different from a Ramist method of hierarchies, different from a patriarchal positioning of supervisors over teachers and teachers over students, and different from mathematics as what *is*. In (re)imagining what mathematics can be, it is important to recognize how mathematics is currently construed. May mathematics education be(come) a field of study that allows for differences, multiple perspectives, and authentic questions, where ideas do not converge or diverge but co-emerge.

Chapter 1 Introduction: Considerations of Pedagogy Concerning Mathematics "Methods" Courses

Teacher education courses that focus on the teaching of specific content areas in elementary grades are traditionally called "methods" courses. The four curricular foci are usually language arts, social studies, science and mathematics. The course I have taught is *Curriculum Disciplines: Mathematics*. This course is taught in conjunction with *Curriculum Disciplines: Science* (taught together as a "block"). These classes occur in the senior year for students, just before their practicum experience. My primary focus is on the pedagogical[1] and epistemological[2] considerations pertaining to elementary education mathematics methods courses.

Over the past three years (five semesters), I have had the privilege of teaching the elementary education mathematics methods course at a major research university located in the deep south of the United States. Through experiences with different groups of students, I have been able to re-work, re-fine, and re-think my pedagogical considerations for this course. Changes have occurred with respect to my epistemological assumptions, pedagogical strategies, and ways in which I listen to my students, leading to my learning to teach complexly.[3] In this dissertation I will explore how teaching complexly continues to develop and what has changed thus far.

One of my initial goals in mathematics teacher education is to engage pre-service teachers in conversations about mathematics[4] that provide opportunities to consider multiple

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[1] I use the word "pedagogical" to imply instructional applications and teaching practices.
[2] Following Gregory Bateson (2002), I employ "epistemological" in reference to theoretical interpretations for "*how we can know anything*" (p. 4).
[3] Teaching complexly comes from William Doll (2005), and the idea relies on maintaining a complexity sciences perspective in which relationships and interconnectedness are of primary concern. Teaching complexly also involves recognizing students' interests and working with them in divergent ways. (For example, Doll has groups of students in the same class reading different books. His idea stems from his research on Gregory Bateson [2002].) The notion of teaching complexly is developed in more depth in Chapters 4 and 5.
[4] The word mathematics refers to mathematical content as well as its historical and cultural locatedness.

ways of perceiving and solving mathematics problems. My intent is to open up interactions to listening that goes beyond paying attention to particular ideas or misunderstandings and moves toward hermeneutical listening (Davis, 1996)—listening that is not focused on pre-determined answers but is open to conversation, to negotiation, and to intellectual meanderings. Another goal is for my students to recognize their situatedness in these pedagogical conversations. Not only do these pre-service teachers bring with them many hours of experience as students in mathematics classrooms—including at least twelve university semester hours—they also are completing their last semester as a university student and making a transition to teacher. This creates a unique position that can present opportunities for conversations about what it means to be a student, a teacher, and how tensions between those two can be negotiated. Involved in this conversational exploration is the challenge for students to recognize the ways in which they were taught mathematics and to reflect on how this might affect their approach to teaching. To facilitate thoughtful, reflective movements beyond either perpetuating or reacting to the ways in which they experienced mathematics teaching, I propose a pedagogy that engages students in conversations that play with mathematical ideas; I provide texts that explore theories of learning and teaching, and I offer pedagogical challenges with which they (sometimes we) can struggle as together we develop our understandings of mathematical concepts, beyond only algorithmic knowledge.

I begin each semester by providing opportunities for pre-service teachers to articulate their epistemological beliefs, and I facilitate ways for them to recognize how these beliefs influence their pedagogical choices. My assumptions here include the notion that students formulate pedagogical points of view that are in part responses to personal educational experiences. Recognizing their own situatedness and learning more thoroughly about different learning theories will, I hope, bring about a more conscience transition to becoming a teacher.

Before articulating my research questions on how complex conversations[5] can support both teacher candidates (my students) and their teacher (me) in being more effective, inquiring, reflective pedagogues, I wish to point out some of my students' initial assumptions concerning methods for teaching, especially in elementary school mathematics. I will also look at the concept and history of method itself, as well as the nature of mathematics. I begin with five semesters of stories derived from personal experiences in my mathematics "methods" course. These stories provide themes that I will explore and develop in later sections of the dissertation.

Teaching as Telling

In the span of the three years in which I have taught a curriculum disciplines (mathematics) course for elementary education majors, the majority of my students have been female, white and of traditional age (20-23 years old). Below is a table indicating the number of students who do not fit into these categories who were members of my classes:

Table 1.1 Demographics of students across five semesters.

Semester	Male	Non-white	Non-traditional Age	Class Size
Fall 2002	1	6	9	23
Spring 2003	0	3	0	30
Spring 2004	0	0	1	31
Fall 2004	1	0	0	18
Spring 2005	1	1	1	20

The fall 2002 semester is noteworthy because at the time the university sponsored an alternative certification program. All of the non-white students were of non-traditional age and current classroom teachers. Two of the other three other non-traditional students were also classroom

[5] Complex conversation is a new term. Throughout my study I use this phrase, and in doing so I hope to stimulate some initial ponderings about what is a complex conversation. In Chapter 5, I focus specifically on complex conversation and attempt to "frame" such a pedagogical strategy—not frame in the modernist interpretation but in a living structure, fluid interpretation.

teachers. Because of their experiences and situations, these students brought forward a remarkably different set of conversations from the other semesters. Their overall expectations, however, seemed to be the same as all of the students in all of my classes at the start of each semester, as described below.[6]

Teacher education students begin our semester together with the expectation that I will teach them "the way" to teach mathematics to elementary students; they express this in their first class journal. William Doll (2005) attributes this to the assumption in educational methods courses "that knowledge itself can be 'handed-on.'" As he says: "Students seem desirous of having such knowledge/methods handed to them and many a methods teacher is willing to comply" (p. 21). The first month in my class is usually a struggle for students because I refuse to engage with them in this kind of discourse. I believe their interest in a telling-receiving discourse stems from their experiences with modernistic, rationalistic pedagogical practices, which I am working against. In fact, I set up the discussion format in class so that opportunities for students to ask me, the instructor, directly how our readings and discussions pertain to teaching will not arise. I resist responding to the specific question—tell me "what works"—for I believe that in time, they will come to an answer for themselves. I do not think anything I say will alleviate their initial fears and concerns. Through activities, assignments, and conversations, these pre-service teachers begin to suggest how they believe the readings and our conversations about the readings relate to teaching in the elementary classroom. I find that this is a much richer and more meaningful experience for all involved. My focus is moving away from teaching as telling and toward alternatives found in conversations—in particular, complex conversations—that generate

[6] Throughout this dissertation, as I share individual students' writings and comments, I use pseudonyms. Students' quotes, which come from course assignments, are italicized. When a majority of students communicates a particular perspective, I speak in generalities about my overall impressions of the class. That is not to say that every student agrees with everyone else all of the time; rather, I am drawing upon collected comments and reflections in which a majority of students communicates one particular opinion.

new ideas and transform all who are involved. Our usual sense of conversation today—"an interchange of thoughts and words; familiar discourse on talk"—is actually the seventh definition listed in the *Oxford English Dictionary* (1989). The first one on the list, coming from the Latin of frequent abode (dwelling) or intercourse (with persons), is "the action of living or having one's being *in* a place or *among* persons." A complex conversation has the particular purpose of developing richness in one's being, in the action of one's living. In this sense a complex conversation is directed toward exploring multiple relationships and interconnectedness. Conversations that are complex involve openness and open endings, shared experiences, relationships rather than hierarchical structures, and dynamical interactions in which all are transformed, including participants and information. Not all interactions are conversations, nor are all conversations complex. It is only in reflecting back on interactions can someone recognize complex relations.

In these (complex) conversations, many students share their histories of experiences in elementary, secondary and postsecondary mathematics classrooms as learning the steps to solving problems. While some have experiences with the use of manipulatives[7] in their educational histories, they still maintain that students need to learn mathematics by being told how to proceed through a problem, even with hands-on activities. Thus, assumptions they bring into my class include the notion that I have the answer to the way to teach particular mathematical concepts, and if I would just tell them, they could learn it and repeat it back to me, as well as (re)produce and perform it in their own teaching.

Simple questions at the beginning of each semester reveal that teacher education students seem "conditioned" to determine what tricks an instructor is employing to produce a

[7] Manipulatives are hands-on materials used that are intended to engage students in visual and kinesthetic representations of mathematical concepts. The problematic of whether or not the use of manipulatives in mathematics is important for prospective teachers (or even experienced teachers) will be discussed in Chapter 2.

regurgitation of the course information that is aligned with the instructor's perspective. I realized this in reflecting upon the situation that became problematic in my first semester (Fall, 2002) of teaching a mathematics methods course, specifically with a student named Jenny (pseudonym). In one journal entry she wrote: "*I can read Davis (1996) and sit in my education classes and act like a little sponge, but in reality I have my own way of wanting to do things*" (Jenny, Fall, 2002). Her statement elucidated her feelings of alienation in my course with respect to her personal beliefs. How could such a response occur, when I was trying to empower teacher education students through articulations of their own pedagogical perspectives? Her words pierced my pedagogical soul, and my spirit was disheartened. Did she not realize I wished her to develop and articulate her "own way," not just soak up my (or anyone else's) way?

My expectation was not met. I believed that if I allowed students to write their own mathematical autobiographies and discuss their own connections to the course materials, they would embrace the freedom to give their own answers, not some preset agenda or pre-scripted response for which I would be looking. The disconnect between her statement and my overall objective for this course—that students would begin to define their personal epistemological underpinnings and pedagogical strategies—haunted me, haunts me even today. Just as Doll (2002) tells ghost stories, stories about those who have made significant impacts in educational history, I share this story as a way to communicate how my past might inform my present and lead into future experiences—how Jenny has made an impact on my current approaches in teaching. Upon considerable reflection of what has occurred in my interactions with students, I strive to be transformed by their words. I encourage students to share with me their current understandings of theory and practice. I then embark on the arduous task of providing an environment that nurtures moments for transformation,[8] ones that emerge from classroom conversations, field experiences, journal reflections, final projects, and all of the communications that occur in between. As I work with my class, struggling through mathematical concepts and curricular creations, I still hear the words of Jenny, calling, haunting, reminding me. So I strive to listen, to consider, and to facilitate moments for connections rather than spur more separations.

At the outset of this particular semester, Emily (Jenny's classmate) seemed to maintain a similar position. Emily articulated her frustrations to me on numerous occasions: she was afraid she would not know how to teach mathematics by the end of the semester because I was not telling her. After many weeks of struggling, Emily began to articulate her own thoughts and enjoyed her classmates' support and affirmation of her thoughts. She emerged as one who was passionate about her own ideas for teaching and not afraid to express them. In her final exam, she wrote her essay in the form of a poem. One excerpt given below displays some musings about her thoughts on teaching:

Enactivism tells me that they will learn more

if I allow them to question, to play and explore.

How easy for me to just give them the facts,

but how much would they learn and how would they react?[9] (Emily, Fall, 2002)

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[8] According to the *OED*, as early as 1432 the word transformation was used to describe "the action of changing in form, shape, or appearance; metamorphosis." Transform is the root word for transformation. In transitive form, the verb transform means to "to change in character or condition; to alter in function or nature," while the intransitive form is defined as: "to undergo a change of form or nature; to change." Transformation can be interpreted as transitive and intransitive, depending on one's perspective and intentions. In this study I employ the interpretation that we are all in transformation, that we are changing our own self as well as having an effect on others. It is a mutual interaction of interplay. This interpretation is in spirit with Huebner's (1987/1999) vision for teaching and education, one that embraces and encourages a community of support and mutual respect.

[9] Emily refers to enactivism in her personal pedagogical point of view. This epistemology comes from Brent Davis's (1996) *Teaching Mathematics: Toward a Sound Alternative*, which we read in class. Her reference here to enactivism is not echoing my own epistemological perspective, as I will explain later. She chooses enactivism as a

Emily's poetic reflection with respect to our class conversations exhibits her transition from original assumptions of fixed ends toward a more open-ended approach. She was willing to forego the assumption that students should be told the facts and instead engages in envisioning a playful learning environment. Somehow, she was able to move beyond the notion of mathematics teaching as telling and to shift toward a more lively, more conversational discourse.

Over the years I have worked towards sharing the value of this recognition with my students, in nuanced ways. My epistemological underpinnings include research in complexity theory, curriculum theory, and hermeneutics. I rely on the works of scholars within these respective fields, as well as conversations with them, to inform how my pedagogy is continuously developed. Taking from Gregory Bateson (1969) the notion that "a difference which makes a difference *is* an idea" (pp. 271-272), I like to engage in ideas about how students' frustrations (methodological tensions) become part of my pedagogy.[10]

The following spring (2003) I introduced a new component to the course, in which I asked the students to submit a problem of the week for us to discuss each Thursday.[11] When I introduced this, I heard many grumblings from my class. Curious as to why this activity would elicit such a response, I paused and asked for the reason to their obviously charged reaction. They told me there is a university mathematics course in which elementary education majors enroll prior to their "methods" classes that uses problems of the week. According to my students,

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response and resists the dominant ideologies of habituation, construction, and enculturation, as outlined by David Kirshner (2002). My choice to use her poem here is to focus on her recognition that teaching mathematics is not meaningful if she merely "gives them the facts."

[10] This is part of what William Doll (1993) considers "provocatively generative"; for just the "right amount" of "*problematics, perturbations, possibilities*" gives the "curriculum not only its richness but also its sense of being" (p. 176).

[11] This idea was suggested by William Doll, after his participation in a conference in Canada with Thomas Kieran. The notion of problems of the week, however, was not a "new" idea for me. I used them when I taught junior high mathematics. What is different is the playfulness. These problems are more like what Stephen Brown and Marion Walter (1983) call problem posing, which "can create a totally new orientation towards the issue of who is in charge and what has to be learned. Given a situation in which one is asked to generate problems or ask questions—in which it is even permissible to modify the original thing—there is no *right* question to ask at all" (p. 5).

their instructor was extremely rigid in how the solutions could be written, and precise work had to be shown at each step. I was fascinated by this because my reason for introducing problems of the week was to provide an impetus for us to consider alternative approaches and solutions, to play with mathematical ideas. I shared this with the class, and while some breathed a sigh of relief, there was still that wary look in their eyes. “Can we trust her?”

The problems of the week became one of my and the class’s favorite times. Students would volunteer to show their answers, others would shout out, “I solved it in a different way; can I show everyone?” and the general tone of the class was one of mathematical conversations that opened up possibilities to recognize multiple ways of knowing. By the end of the semester, many students verbalized their enjoyment with these problems as well, and would often contrast their feelings with their experiences in other mathematics courses that were rigid and restrictive. This contrast provided a way for them to talk about personal pedagogies and how their future classrooms would allow for conversations and multiple perspectives.

In this manner, teaching complexly involves continual (re)consideration of positive and negative feedback to refine (or maybe re-find) one’s sense of pedagogy. In response to both Jenny’s and Emily’s comments, I continue to contemplate how to encourage my students to embrace their perceptions of learning, even as I search for ways to foster moments that might bring about epistemological shifts in their (and indeed my) perspectives. Using this dual approach of embracing and transforming, my teaching experiences continue to be both challenging and engaging. In the spring of 2004, I again met with critical comments towards my choices for the pedagogical focus of the class. One elementary education student, a gifted scholar and a full-time dance instructor, was probably the most outspoken against my conversational practices. She continually informed me that our work in this class was purely theoretical and had no practical substance, thus would be of no value to her when she entered her classroom. The words she wrote in her midterm exam, however, seem to tell another story:

> *Looking at my own experiences, the orientation I described above almost always happens naturally when I teach. Even when I think I have planned the perfect dance class, what actually happens always deviates from what I originally set out to do. The class still maintains its productivity, but tends to accommodate my students' needs and explore[s] possibilities that I would have never expected. Davis (1996) also says, "One never knows exactly what one will learn" (p. 90). I find this phenomenon occurring because of my students' interaction with the knowledge that I have set in front of them. They take what I give them and make it their own. My instruction, therefore, must proceed from this point. Kincheloe et al. (2000) state, "While the past informs and conditions the present, every moment also contains possibilities for change and new directions" (p. 309)*. (Laura, Spring, 2004)

Reading her text, I sense her attempt to find some connection between the course readings and her experiences. She moves beyond what Jenny stated about pretending to be a "little sponge" and engages at some level with the course texts and class conversations. Her frustration with my pedagogical strategy of not showing the way to teach mathematics, I interpret as contrasting with her epistemological belief of setting the knowledge "in front of" students. I believe that she is one of those students who would not just take an instructor's position and accept it as her own, but rather negotiate how it is consistent with or in contradiction to her own pedagogical strategies. I also believe that her vast experience in the dance classroom and her age (she is a few years older than other students) creates a different perspective. Her experiences in dance instruction allow her to develop her own teaching style. Her inexperience with (and possible fear of) teaching mathematics causes her to want to adopt someone else's method—a proven method. The epistemological leap from her past experiences to new ones is a struggle for her.[12]

For Laura, the problems of the week were not enough. How do I consider the comments made by her as a way not only to help her develop her pedagogy but also to help me question and refine my pedagogy? My goal for the next semester was that playfulness might permeate every class conversation and activity. My pedagogical hope was, and continues to be, that pre-service teachers might shift their perceptions of mathematics from precise, right-wrong structures toward multiple ways of knowing. Current modernist frames of mathematical teaching still maintain dichotomies and exact methods, yet mathematics itself is a field of study in constant flux and continual discovery. Allowing for the fact that most, if not all, of these teacher candidates have participated only in a modernist, set paradigm with respect to mathematics, how might I provide moments for them to know in different ways, ways that engage them in play and embrace difference? This question arises or "pops up" when one adopts a post–modern frame.[13]

One way to utilize difference is to provide different activities each week to stimulate conversation and challenge students' understandings of particular concepts, for both mathematics and for teaching. I have used one activity that involves students physically walking the Cartesian coordinates on a tile floor mapped out by yellow tape as a way to create a common experience that becomes a referent for conversation. The students separate into four groups, and each group has a volunteer walk the coordinates provided by another group. If the student does not move to the correct location, another group can challenge, state the correct solution, and win their team a

[12] Michael Glassman (2004), in an article entitled "Running in Circles: Chasing Dewey," points out that "transfer" of method—here from dance teaching to mathematics teaching—is not direct, is a skill in and of itself, and requires time and practice. It might be thought of not as just an epistemological loop but as an epistemological creation.
[13] For differences between modern and post–modern frames, refer to William Doll (2003), *A Post–Modern Perspective on Curriculum*. For myself, a post–modern frame is one that embraces multiple perspectives, utilizes difference, eschews rigidity, and thrives on questioning.

point. Additionally, the student who is walking can earn a bonus point if she can state in which quadrant she is standing when finished. In one situation, while each student was able to walk to the correct location, the first three guessed the quadrant incorrectly. I did not correct their guesses nor allow other students to vocalize a guess. For a while, I merely did not assign a bonus point, so there was an unknown, an untold, and a perturbation existed until someone finally guessed the correct quadrant. Once that guess was honored, other students began to see the pattern for how the quadrants are numbered—counterclockwise[14]—and they answered correctly for the duration of the activity. At no time did I as the "teacher" tell them the numbering pattern. I merely awarded a point to the group with the correct answer. The groups discussed the quadrants and concluded (remembered from previous instruction) that the quadrants are numbered counterclockwise.

After a sufficient time of performing this activity, I facilitated a conversation about what was involved. One student shared that my not telling them the correct quadrant led them to want to find out the answer on their own. Another student said she would remember plotting coordinates now because she had "done" it. Interestingly, she was one of the students who did not physically stand up and plot a point. I raised this argument, and she claimed that even though she did not personally walk, she was walking in her mind. Her statements brought forth a fascinating idea for me, one that I started noticing with this class. A sense of the collective was emerging with this group of students. In their personal reflective journals that semester, many students used the words "we now understand" and "we did not know." I criticized this type of pronoun usage and informed the students that they could really write only about what each, as an

[14] An interesting historical question is why the quadrants are labeled in counterclockwise order. (A colleague who read this question sought an answer by "googling" the Internet. He shared with me that he found over and over again the reason is "it is tradition." He then commented that it seems historical meanings and relevance of many mathematical concepts have been lost somewhere along the way.)

“I,” now knew and understood rather than the collective “we.” But is that really the case? I assign reading that they are required to summarize before class, then we all come together for conversation, and they are to follow up with a journal reflection of our conversations. In these first journals, there was a general leaning towards the use of the personal “I.” The collective “we” surfaced in the journals that followed class discussions, when the knowledge became understood as a group. Did, in fact, each student truly not understand as an “I” but learn as a “we?” If students do understand as a “we,” what are “we” in education courses doing to develop and nurture a sense of “we–ness?”

Considerations of Method

Drawing on the past three years of experiences in teaching mathematics education courses, I recognize that each semester pre-service teachers assume I will teach them the way. I believe this trend will continue. In more than just mathematics education, current methods in education courses encourage a one-right-way approach, do not utilize different perspectives, convey the belief that knowledge is imparted directly to students, and leave unexposed epistemological assumptions. From where do such methods and assumptions come? A brief study into the history of “method” exposes some of those assumptions that are now prevalent in teacher education courses.

According to the *Oxford English Dictionary* (1989), the word method originally comes from the Greek word *methodos*, which means “pursuit of knowledge” (*O.E.D.*, 1989). So how did “method” become a term affiliated with curriculum, currently maintaining a more superficial understanding in education, namely that it represents a notion of pedagogical implementation of subject matter in a classroom? Method is a technique, “a particular procedure” (*O.E.D.*, 1989), implying a prescribed *operand* that ensures student achievement.

Many educational researchers point to René Descartes (1596-1651) as the original author of method within modern times (e.g., Solomon, 2003). Descartes, a contemporary of Galileo Galilei (1564–1642) and Francis Bacon (1561–1626), searched for ways to move from doubt to certainty. Descartes' method "consists of (a) accepting only what is so clear in one's own mind as to exclude any doubt, (b) splitting large difficulties into smaller ones, (c) arguing from the simple to the complex, and (d) checking, when one is done" (Davis and Hersh, 1986, p. 4). Using this method, one could use logical steps to arrive at a certain conclusion. Descartes's project provides a "sense of Reason which is beyond the reasonableness of human doubt" (Doll, 2005, p. 41). These four steps are found in many current pedagogical frames, such as Ralph Tyler's rationale[15] and Madeleine Hunter's model.[16] Influences in Descartes's method, however, can be traced back to philosophers in the Renaissance era, and to contemporaries of Descartes.[17]

Stephen Triche and Douglas McKnight (2004) expound upon the historical significance of Peter Ramus (1515-1572), whom they claim was the first to produce the modern notion of method, particularly his "one and only method." Ramus' approach was a significant departure from educational practices that existed at the time. According to Triche and McKnight (2004), Peter Ramus conceived of a new method in which knowledge could be reduced to simplified, discrete bits. "Ramus' primary intellectual accomplishment," Triche and McKnight (2004) claim, "was the refinement of the art of dialectical by transforming dialectical reasoning into a single method of pedagogical logic for organizing and demonstrating all knowledge" (p. 40; emphasis added). Ramus created this method in response to the work of scholasticism which

[15] The Tyler rationale includes moving through the four steps of purpose, experience, organization and evaluation.
[16] Madeleine Hunter's (1967) model involves seven elements for writing an effective lesson plan: (1) objectives, (2) standards, (3) anticipatory set, (4) teaching (input, modeling, and check for understanding), (5) guided practice, (6) closure and (7) independent practice. For some current examples, see Allen (1998) and Kizlik (2005).
[17] Doll (2005) traces what he terms as "family resemblances" of curricula that have evolved from the works of Ramus, Comenius, Descartes, Taylor and Tyler, and alternatives or variations found among Galileo, Bacon, Vico, Pierce, James and Dewey.

demonstrated little purpose or practical usefulness. His vision was to create *a way* to analyze, interpret, work through any information, with a "pedagogical purpose [that] was practical and expedient—transform[ing] scholasticism's rigorous and difficult, but impractical, educational practices into a simplified enterprise 'useful' to the student" (p. 42). He invented the word "curriculum" to describe what he created: "A system for dividing and arranging knowledge into discrete categories, thereby making it easier to teach (*doctrina*)" (p. 40).[18]

This shift from the dialogical, linguistic tradition led to written, textbook-driven pedagogical practices, when Ramus' notion of method became influential in (late) 16th and 17th century Europe and America. The ability of students to learn became dependent upon their ability to analyze (map, chart) a text, a process which removed information from its context (Triche and McKnight, 2004, p. 49). Efficiency and practicality became more important than reasoning and invention. Ramus postulated that learning procedures should follow the pattern of defining and dichotomizing knowledge. From these branches, smaller portions of "truths" could be learned in more precise ways. This shift in method reveals a shift in goals, namely that students should demonstrate they "know" specific information rather than show how they could logically reason through a situation. This practice can be found in our educational system today, where we center our pedagogical procedures on textbook knowledge that has been dictated to us—the learner demonstrating her knowledge in discrete bits. This type of practice stems, in part, from the Puritan adaptation of Ramus' dichotomized logic and curriculum maps, which "found a home at Harvard from its inception in 1636 and spread across the New England townships and countryside, permeating New England institutions, including family, school, vocation and church" (Triche and McKnight, 2004, p. 40). Ramus' method, revolutionary in his time, is situated within the beginnings of modernity, and has influenced this tradition with its emphasis

[18] The Ramus Map can be found in Doll (2005), where the word curriculum was first used by Ramus (p. 25).

on "textbookizing" knowledge: removing knowledge from its context and breaking it into discrete pieces, sections, disciplines.

William Doll (2002) problematizes Ramus' "methodization" as pandemic in education today. In Gregory Bateson's (2002) terms, the map has become confused with the territory. Assumptions for how knowledge is structured have influenced how information should be taught. This rigid interpretation of knowledge structures has generated a narrow interpretation for curriculum. Doll (2002) recognizes the impact Ramus has made in education:

> This skeletal outline or logical map of knowledge on which the ramifications were to be placed was, Ramus believed, universal in scope. It was a general outline to fit all knowledge. Further, and this is crucial, he thought the outline mapped not only the structure of knowledge but also *the structure of acquiring knowledge*. (p. 31)

This problem, of Ramus believing that his constructs are how knowledge is structured, and taking it even further to believe how knowledge is acquired as well, has created a perspective of education in which teaching and learning are transferred into linear, universal, and simple methods. Our textbooks today reinforce this perspective.

I believe these issues are relevant to my research and to the responses my work elicit from pre-service teachers. Further, I believe that mathematics is particularly pertinent because of the ease with which the content can be structured in such hierarchical relationships (ramifications). Thus the influence of modernist knowledge structures plays an important part in pedagogical interpretations for mathematics instruction. In Chapter 2, I examine how mathematics education textbooks follow this type of structure in their organization and the impact this form has on epistemological and pedagogical perspectives in mathematics education.

Methods in Education

How do these interpretations of methods come into play in education? Doll (2002) recognizes the extent to which Ramus's influence has created serious repercussions in teaching:

> Methods professors and teachers-in-training each harbor the hope that such courses will yield efficient "short-cuts" to the way knowledge is both structured and acquired. This has proven to be a forlorn and deceitful hope. Knowledge can be structured in many ways; the ways chosen for such structuring bear neither a direct nor a necessary relation to the way knowledge is acquired…. Confusion between these two has done immense damage to pedagogy and curriculum theory. (p. 33)

Ramus's reductionist approach simplifies knowledge into subsets, in which logics of linear and hierarchical structures are imposed upon concepts. To reiterate, current assumptions about methods center around notions of the way, rejection of difference, and knowledge as transmitted into students.

Underscoring these assumptions are the works of Descartes and Ramus and their quest for *the method* and *the one and only method*, respectively. Following Ramus and Descartes, teaching "underwent a paradigmatic change—from dialogic glosses on ancient and honored texts and even from glosses on those glosses to a direct, 'short-cut' route to a desired and prescribed end. Epistemology became practical and teaching became methodized" (Doll, 2002, p. 30). These approaches have become the logic for how curricula are structured, how textbooks are organized, and how each subject is reduced into smaller, dissected parts. Instead of perceiving method as universal, linear, and simplified, I would like to consider a different kind of method, "not the pedagogy of mimesis (copying) but the 'pedagogy of practice' wherein the practice is not mere repetition but the practice of doing, reflecting, visioning, doing yet again with a 'difference'" (Doll, 2005, p. 52; see also Trueit, 2005b). This form of doing, reflecting, visioning, and embracing difference is not prevalent in teacher education courses. I will now examine some of the history of teacher education in the United States and how the field has evolved.

Teacher Education

As a path for understanding why pre-service teachers begin our semester with particular assumptions and expectations, I look to a partial history of teacher education as a way to interpret how the current rhetoric in teacher education has emerged. Understanding is a key concern for those in the field of education. Following William Pinar, William Reynolds, Patrick Slattery, and Peter Taubman's (1995) contention that in order for us "to begin to understand curriculum comprehensively it is essential to portray its development historically" (p. 69), let us consider different historical interpretations about the field of education and how it has evolved, specifically in the works of Pinar (2004) and Pinar et al. (1995).[19]

Pinar et al. (1995) trace histories of American education starting with the publication of the 1828 *Yale Report*. They highlight key movements and scholars throughout the nineteenth and twentieth centuries, then describe how a publication (*NSSE Yearbook*, 1927) concerning the history of curriculum studies from various curricular orientations, including the highly disputed groups of the social efficiency and progressive movements, legitimatized curriculum as a field in its own right. In the early twentieth century, education scholars became concerned with behavioral objectives, life-adjustment concerns or democratic ideals. All seemed to work together to generate a tension in the field that stimulated further growth within each curricular perspective.

[19] In Chapter 2, I explore interpretations of understanding and how these interpretations influence instruction.

Two events spurred a significant change in American education following World War II. One was the launch of Sputnik by the Russians in 1957, which created a reaction that led to criticisms of education by those obsessed with science and technology. Pinar (2004) depicts this situation as one of exploitation by those in power over compulsory schooling, for "this crisis in national security was 'displaced' onto curriculum planning, in effect, the stipulation and control of what is taught and learned in school" (p. 210). The focus of education became science and mathematics as a way to discipline and "'toughen' the mind" (p. 93). Policy makers exploited the anxieties about the Cold War by blaming education for our failure to beat the Soviets (Pinar et al., 1995, p. 154).

A second event that created a change in education from more progressive, liberal, democratic ideals towards a rigorous, efficient, and disciplined perspective was the publication of Tyler's (1949) *Basic Principles of Curriculum and Instruction*. This book allowed for a more generalized view of education, shifting the focus from child-centered approaches to behavioral objectives. Following, taxonomies about how to successfully accomplish the four categories of the Tyler Rationale—purpose, experience, organization and evaluation—emerged. This line of thinking has evolved into accountability systems that "measure" success in education.

Pinar et al. (1995) offer hope for education by presenting how a reconceptualization of curriculum can stimulate growth and change in the direction of more democratic notions of education. Simultaneously, Pinar (2004) criticizes the anti-intellectualism that is pervasive in current educational policies, in the accreditation procedures of NCATE (p. 214), and in the business models of education (p. 164). With both the hopes and the critiques presented, instead of accepting the duty of ensuring that "students 'learn' what others… declare to be worth learning" (p. 209), we as curriculum scholars can invite change to the ways we might answer the questions, "Why educate?" and "Whose knowledge?" Understanding becomes interpretations of content knowledge, epistemologies and pedagogies, and understanding involves considering how we are constantly in flux, that knowledge changes as we change and we change as knowledge changes.

Teacher education reflects as well as impacts the societal assumptions prevalent in the field of education. Following trends in education over the last 50 years, Marilyn Cochran-Smith (2004), president (2004-2005) of American Education Research Association (AERA), proposes that the "'problem of teacher education' [could be framed] in three quite different ways: as a training problem, a learning problem, and a policy problem" (p. 295). These three distinct problems reveal the research methodologies considered "valid" at the time and distinguish suggestions for how teacher education should be conducted. Outlined below are her three categories and how they are situated historically within the field of teacher education.

In the shadow of World War II and Russia's launch of *Sputnik*, a procedural view of teaching became the frame in which mainstream teacher education functioned. The significance of this method was a "technical view of teaching, a behavioral view of learning, and an understanding of science as the solution to educational problems" (p. 295). Modeling "approved" teaching behaviors was the focus, and research proved the educational significance of this through empirical studies. During this era of teacher education, critiques arose, and the "most damaging critique," contends Cochran-Smith (2004), "was that… the focus was on 'empty techniques' (Lanier, 1982) rather than knowledge or decision making, and thus, the approach was atheoretical and even anti-intellectual" (p. 296). Out of this critique, as well as many others, a shift in considerations for teacher education occurred:

Teacher education became a learning problem. Within this construction,

> the point of research on teacher education was to build and explore the professional knowledge base, codifying not only how and what teachers should know about subject matter and pedagogy but also how they thought and how they learned in preservice programs and schools and the multiple conditions and context of what shaped *their* learning. (p. 296; emphasis added)

Following this movement, research became more qualitative in methodology, incorporating questions about how teachers formed their own knowledge. The goal was to allow prospective teachers to consider how they continue to learn throughout their lifetime, and as that changes, how it would affect their classroom practice. In response, critics of this new approach accused teacher preparation of being too focused on progressive and constructivist perspectives and out of touch with public interests. Furthermore, by focusing on "teachers' knowledge, skills, and beliefs without adequate attention to pupils' learning" (p. 297), connections between learner and teacher were underdeveloped, which resulted in distancing or even severing links between reflection and pedagogical implementation.

An extreme rejoinder surfaced, shifting the problem of teacher education towards issues of policy rather than learning. The most severe response is the creation of the *No Child Left Behind Act* (2002), with its agenda to provide "highly qualified teachers." Within this law, Cochran-Smith (2004) perceives "a return to the training view of teacher education" (p. 298). The severity to which this policy focus affects teacher education is demonstrated in the requirements of testing and measurement of student learning, the results of which policymakers hold teachers and schools accountable. Thus the shift in teacher preparation back to a technical view reveals the epistemological assumptions of policymakers, not educators. The policies that are in effect today, according to Cochran-Smith (2004), "do not come about as the result of simple common sense or expediency alone, nor are they disconnected from values and ideology, from existing systems of power and privilege, or from assumptions about what is mainstream and what is marginal” (p. 298). Significantly, those in positions of power and privilege impose their values and assumptions in the classroom, thereby affecting how teachers are to perform their jobs, thus affecting how teacher education programs structure their curriculum, which in turn affects how teachers implement their pedagogy, and so the circle continues.

Reactions to this cataclysmic shift in teacher education remain to be seen. Marilyn Cochran-Smith (2004) offers a pragmatic response, providing not an extreme rebuttal but rather an incorporation of policies coupled with current educational research. She claims that

> teaching has technical aspects to be sure, and teachers can be trained to perform these. But teaching is also, and more importantly, an intellectual, cultural, and contextual activity that requires skillful decisions about how to convey subject matter knowledge, apply pedagogical skills, develop human relationships, and both generate and utilize local knowledge. (p. 298)

In her statement, Cochran-Smith exhibits her belief that teacher education should focus on all three aspects of the problem of teacher education, namely the problems of training, learning and policy. Considerations in all three areas could position teacher education as shifting more towards a pragmatic method that engages with all three aspects.

One example of a shift in trends for teacher education is displayed in research conducted by Linda Darling-Hammond, Ruth Chung, and Fred Frelow (2002), surveying new teachers in New York City and focusing on teachers’ feelings of preparedness. In their study, they found an example of an outstanding teacher education program, one that demonstrates an increase in the confidence of prospective teachers. This program, Bank Street, combines classroom experience, intellectual reflection, and course study for their students as they progress through the program (Cochran-Smith, 2004, p. 293). Democratic ideals and progressive education are primary emphases at Bank Street, and prospective teachers study these as well as work with teachers who exemplify these ideals. Cochran-Smith (2004) concurs with this path of teacher preparation by emphasizing that “how to prepare teachers to foster democratic values and skills must be acknowledged as a major part of the ‘problem of teacher education’ if we are to maintain a healthy democracy” (p. 298). By tracing histories of education, we can grow in our understandings of learning and teaching, and from this consider the benefits and weaknesses of our current situation. Now I would like to shift the conversation to structures of mathematics and how its perceived structures influence ways in which it is taught, “handed-down,” passed on, not created, invented, questioned, envisioned.

Mathematics: Created or Discovered?

What is the nature of mathematics? The nature of mathematics is a philosophical question, one that stems from particular metaphysical and epistemological perspectives. There exists one area of mathematical study that is primarily concerned with histories of mathematics, and in presenting these histories, philosophical interpretations are considered. For example, Paul Ernest (1985, 1994), an advocate for the incorporation of historical contexts in the instruction of mathematical concepts, frames various mathematical philosophies into five categories.[20] These categories fall within one of two interpretations about the “nature” of mathematics. One perspective relies on the notion that mathematics is externally conceptualized, waiting to be

[20] Ernest’s (1985) five categories include: Logicism, Formalism, Constructivism, Platonism, and Fallibilism. Logicism adheres to the notion that pure mathematics is part of logic. Formalism remains fixed on formal systems with proofs that are consistent within the embedded system. Constructivism looks to the process wherein mathematical objects have meaning. Platonism maintains that “the objects of mathematics have an independent existence and that mathematics consists of descriptions of the relationships and structures connecting these objects” (p. 607). Finally, Fallibilism considers mathematics as a human endeavor and thereby attempts to describe it as such.

discovered, while the other perspective views mathematics as internally constructed, a human endeavor that is created as it is defined.

Turning the question around, what about the search for the mathematics of nature? The mathematics of nature is a venture pursued by many mathematicians, as well as scientists, as a way to find patterns among, amidst, alongside observations of the natural world. The mathematical nature of waves, rivers, and geologic transformations are all notable pursuits. Often, those studying and proving that nature is mathematical do not adhere to the belief that humans have created mathematics as a way to discuss observations and perceptions in the "real" world and that they are imposing their own patterns upon what they believe to be universal.

The topic of the nature of mathematics includes the question of whether we can truly know the nature of anything, including the discipline of mathematics. Describing the nature of mathematics implies presenting its essence, a problematic term in itself. These descriptions, nature and essence, can be traced back to Plato and his notion that if we could find something's essence, then we can know it. Thus by asking the question, what is the nature of mathematics, then answering it, Platonic logic remains intact. In Plato's forms, mathematics is perceived as an abstract mental activity that seeks what is already in existence. George Lakoff and Raphael Nuñez (2000) propose that this notion was solidified by Euclid, and from Euclid's deduction of reason "came the idea that every subject matter in mathematics could be characterized in terms of an essence—a short list of axioms, taken as truths, from which all other truths about the subject matter could be deduced" (p. 109). Mathematics maintains this structure today, by declaring the frame and working within it to establish what is *known*.

Similarly, John Dossey (1992), in his essay, "The Nature of Mathematics," argues that the contrasting works of Plato and Aristotle constructed two major concerns about the nature of mathematics. For Plato, "the objects of mathematics had an existence of their own, beyond the mind, in the external world" (p. 40). Plato further delineates "clear distinctions between arithmetic—the theory of numbers—and logistics—the techniques of computation required by businessmen" (p. 40). Plato's argument that mathematics is an abstract mental activity elevated its position in scholastic thought. Dossey (1992) then shows how Aristotle challenged Plato's interpretation by advocating for mathematical knowing as experienced reality. Aristotle did not believe mathematics was based on a "theory of an external, independent, unobservable body of knowledge…. In Aristotle's view, the construction of a mathematical idea comes through idealizations performed by the mathematician as a result of experience with objects" (p. 40). This debate, starting with the Greeks, continues today. Dossey (1992) provides an historical tracing of these two perceptions of the nature of mathematics from Plato and Aristotle through current literature, for in questioning the nature of mathematics, there is a long history attached to this idea. This history reveals how the nature of mathematics has been perpetuated as postulated externally, while along the way counternarratives of mathematics as conceived internally have coexisted.

After relating these perspectives to mathematics education and research, Dossey (1992) concludes that "conceptions of mathematics fall along an externally-internally developed continuum" (p. 45). This continuum is where I believe the study of mathematics is still trapped today. Debates from opposing sides of the spectrum do not provide a purview of mathematics that depicts its richness. Lakoff and Nuñez (2000) present arguments from both sides, then suggest that we can move beyond the dichotomy by taking the view that mathematics is a product of embodied cognition. While I am not in agreement with their conclusions that shift towards Buddhism as an alternative, I applaud their attempt to move us beyond the debate of whether mathematics is transcendent (objectively existent) or constructed (individually created). To limit what mathematics could be by keeping its definition within a particular frame is to restrict opportunities for creative, innovative and emergent ideas. To transcend this continuum on which Dossey (1992) proposes mathematics is still moving, we need to consider how mathematics could be defined, not in terms of an "out there" or "in here," but instead as a continual collective knowledge or understanding of patterns and how understanding in mathematics is dynamic.

In considering how to define mathematics, history and culture play major roles. Echoing the sentiments of Petra Munro (1998), in my endeavor to define mathematics, I want to "challenge the myth of progress by conceiving of history as the confluence of processes so interconnected that it cannot be reduced to a single unitary storyline (grand narrative)" (p. 263). One way to create a contradiction, a paradox if you will, would be to consider how mathematics is simultaneously culturally independent and dependent. Consider what Lakoff and Nuñez (2000) offer:

> Mathematics is independent of culture in the following very important sense: Once mathematical ideas are established in a worldwide mathematical community, their consequences are the same for everyone regardless of culture. (However, their establishment in a worldwide community in the first place may very well be a matter of culture.) Mathematics is culture–dependent in another very important sense…. Historically important, culturally specific ideas from outside mathematics often find their way into the very fabric of mathematics itself. Culturally specific ideas can permanently change the actual content of mathematics forever. (p. 356)

By offering seemingly contradictory considerations of mathematics as both culturally independent and dependent, Lakoff and Nuñez (2000) are able to create a sense of mathematics that is dynamic, changing, subject to historical and cultural contexts. Mathematics is historically situated, and while ideas can continue throughout periods of time, these ideas can be challenged, manipulated, and (re)considered in the shifting of ideas and applications. Thus, "the intellectual content of mathematics does not lie where the mathematical rigor can be most easily seen—namely, in the symbols. Rather, it lies in human ideas" (p. XI). Though mathematics (as well as science) claims an objective reality, mathematics is a human endeavor, rampant in human ideals, assumptions, and contexts.

Mathematical symbols form a language, a system that can be translated by those who know how to read and speak in mathematical terms. This symbolic manipulation romanticizes mathematics as a mystical, almost priest–like activity. Margaret Wortheim (1995), in her Western historical analysis of the field of physics,—a mathematically-based science—shows how physicists from the time of the Greeks to the present are perceived as part of a "higher order." She parallels the works of physicists with those in religious positions, showing how the histories of science and religion exhibit a societal deference to meta–physical knowledge. Lakoff and Nuñez (2000) agree that this priest–like quality of physicists (and mathematicians) "perpetuates the mystique of the Mathematician, with a capital 'M,' as someone who is more than a mere mortal—more intelligent, more probing, deeper, visionary" (p. 340). Those who are not Mathematicians are mere mortals and should rely on those who have these higher gifts.

I believe this notion of an elevated position for mathematicians carries over into the classroom. Students consider mathematics as a language that their teacher, with a capital "T", should translate for them, and that the symbolic manipulation has meaning in and of itself. Some students become “fluent,” while others perform tasks that allow them to “pass” with competency (but not fluency). Still others struggle to get by, or maybe they are left behind (or possibly choose to stay behind). At the end, after the required schooling, where are they situated? Those who can “do” mathematics are heralded; even more are the accolades for one who is willing to teach the subject to future generations. This perception of a chosen few who are able to understand mathematics perpetuates Plato’s notion of mathematics as already in existence, as externally represented. Dossey (1992) has found that, when pushed to answer, mathematics teachers will inevitably revert back to the perspective that mathematics is externally conceptualized. While some believe mathematics is a “static discipline developed abstractly, [others] see mathematics as a dynamic discipline, constantly changing as a result of new discoveries from experimentation and application” (p. 39). Either static or dynamic, mathematics is still waiting to be discovered.

Instead of arguing in favor of one direction in the continuum, I refrain from this debate. Later I will demonstrate how mathematics teacher education textbooks fall in line with Dossey’s (1992) conclusion that mathematics teachers will revert back to the perspective that mathematics already exists and only waits to be discovered. For now I will conclude with my research questions and how this dissertation will unfold.

Focus of My Inquiry

In a continual textual and discourse analysis of the conversations and statements that result from my pre-service teachers, I recognize several emergent patterns which I find significant. The first is the importance of interactions and reactions. To imagine teaching as a relationship requires the recognition that teaching does not occur in isolation. To engage in hermeneutical listening[21] requires an open-ended line of questioning that does not pre-set, predetermine, or pre-scribe. Specifically, teaching mathematics as a relational activity—in which a hermeneutical perspective is crucial—brings forth epistemological questions and issues. The term "math methods" is a doubly weighted phrase, for both mathematics and methods connote particular ideologies prevalent in current educational rhetoric. In order to unpack the impact of these words, I engage in research based on inquiry, historical analysis, and personal reflections, all of which I use in an eclectic and explorative manner.

My work is influenced by many curriculum theorists. One scholar, William Doll (1993, 2005), encourages a move from teaching as telling to conversation—a special type of conversation (complex)—that involves consideration of the current location of students. Doll's reiterative patterns of relations inspire me to continually re-find and re-work my ideas of my work. In another way, William Pinar (1995, 2004) inspires my forms of inquiry and historical contexts of knowledge. In the current position of a university instructor, I have often been faced with questions of why theory is important, why curriculum theory is a valid field, and I have even been admonished that when I teach "methods" classes, I need to keep my instruction practical and useful, not theoretical, abstract, or philosophical. Yet I persist in the work of curriculum theory. Why is this? I believe in Pinar's (2004) assertion as to the work of a curriculum theorist:

> We curriculum theorists do not regard our task as directing teachers to apply theory to practice…. Rather, curriculum theorists in the university regard our pedagogical work as the cultivation of independence of mind, self-reflexivity, and an interdisciplinary erudition. We hope to persuade teachers to appreciate the complex and shifting relations

[21] Davis (1996) writes that hermeneutical listening is different from evaluative or envaluative in that the inquirer does not already know the answer. David Jardine, Patricia Clifford and Sharon Friesen (2003) employ the task of "thinking the world together" (the subtitle of their book), based on hermeneutical notions of conversation.

> between their own self-formation and the school subjects they teach, understood both as subject matter and as human subjects. (p. 24)

Cultivating the independence of mind, self-reflexivity, and an interdisciplinary erudition is no small task. Students who are preparing for the professional field of teaching often feel they already have an idea about what it means to teach, based on the countless hours they have spent in relation to teachers (Britzman, 2003). As a curriculum theorist in teacher education, I have set forth my task of challenging pre-service teachers to consider multiple perspectives about what it might mean to be a teacher.

In the midst of this work, I look for and take note of continual transitions, transformations, dynamic changes that are occurring in our work in the classroom. In light of this difference, a key position for me as a teacher is to consider how education is part of an open system, rather than a closed system. An open system, according to Ilya Prigogine and Isabelle Stengers (1984), is defined as a system that exchanges energy, matter, or information with its environment (p. xv). Living systems are open systems, for boundaries are shifting, changing, and renegotiating as the system continues to redefine itself. Open systems differ from closed systems, which are mechanical, predictable and controllable, in that open systems do not remain fixed. Boundaries in a closed system are structures such as walls of concrete, whereas boundaries in open systems are like membranes that are constantly in flux. Living systems are complex systems. Scholars whose research is informed by complexity theory seek

> patterns and relationships within systems. Rather than looking to cause and effect relations, complexity theorists seek to explicate how systems function to rely upon feedback loops (reiteration, recursion, reciprocity) so as to (re)frame themselves and thus continue to develop, progress, and emerge. (Smitherman, 2005, p. 163)

Complex relations are not interpreted as patterns of causalities, dichotomies, nor hierarchies; instead, complex relations are perceived as web-like, interrelated, and parts and wholes always in relation, never to be isolated. Open systems are continuously shifting, changing, emerging.

Complexity theory and interpretations of complex relations connects to education in that "closed systems *transmit and transfer*; open systems *transform*" (Doll, 1993, p. 57). In order to move away from teaching as telling, we should consider how curriculum, students, teachers, knowledge, etc., are part of an open system, and as such transforming all involved. Complex conversations embrace a systems perspective, that is, an open, dynamical systems perspective. And this system is always changing, never the same, and subjective to the one who defines it. Complex conversations in a classroom aim toward transformation, so it becomes important for all participants to contribute actively in one way or another.

This leads to questions of ethical implications for a teacher who appreciates complex and shifting relations. The notion of transformative education carries with it many ethical issues. What ends do I, or any teacher, have? Am I imposing my ends? Should I so impose? Whose politics are involved? If a teacher is working to change or transform students, the question "Why?" needs to be asked. What is insufficient in students' current perspectives that such a change is warranted, needed?

David Jardine, Pat Clifford, and Sharon Friesen (2003) stress that, in fact, teaching is scholarly work (p. 214). They claim that education researchers continually ask teachers to change in order to align themselves with theories imposed by the researcher. That teachers are willing to comply is what Pinar (2004) calls "gracious submission" (p. 71). Who is the researcher, that the ideas put forth in theory are better than those of a classroom teacher? Why do teachers feel compelled to submit? Is it a sense of inadequacy in being able to articulate the ways in which their ideas are just as valid? If this is so, how can we work to empower teachers in the language-games of educational research so they might become participants in the game, rather than just pawns?

In trying to name what I believe my work entails, I initially used the term “therapeutic” (instead of transformative). I employed this with respect to the thought that I was helping my students not perpetuate or react to their experiences in mathematics education, but rather move beyond to recognize both benefits and limitations of what they know. The usage of “therapy,” however, carries with it a connotation I wish to avoid. Erica McWilliam (1994), a teacher educator, elaborates on why the discourse of therapy is inappropriate:

> I began to perceive an apparent pre-service teacher preference for romantic humanistic vocabularies in talking about educational work. “Raising self-esteem” seemed to be a central tenet of this “discourse of therapy,” which had the effect of constructing student/clients as “ailing” or educationally fragile individuals who need the maternal care of teachers. Its driving logic seemed to be a social pathology model of both educational and interpersonal ill health, a model that, it has been argued, privileges the language of “legitimate labelers” such as doctors, psychiatrists, psychologists, and educators. (p. 73)

Thus, I attempt to circumvent claiming a privileged position as teacher educator by adapting Doll’s (2005) notion of a transformative education interpreted in a post-modern, complex frame. This idea is not without its limitations either, but working within a relational, dynamic, interpretative perspective provides opportunities for change, growth, negotiation, and changes the power dynamics at play in the classroom and in education in general—including a (re)imagining of transformative education. I will elucidate how these relate to my personal experiences as a teacher educator in Chapter 4, then explore relations to education in general in Chapter 5.

Edmund O'Sullivan (2002), an education researcher concerned with transformative education, defines transformation as "the reorganization of the whole system. In this process, the viewed world is different and so is the viewpoint of the viewer" (p. 4). Holding to this perspective, both the learner and the knowledge are changed as a result of an interaction. This is a different interpretation than the *Oxford English Dictionary* (1989) definitions of transformation as a transitive and an intransitive verb. A teacher who pursues a transformative pedagogy desires to change others, but this may or may not imply agency on the part of the student. That is why I define transformative learning in the spirit of Dwayne Huebner (1987/1999): "Teachers are called to participate in these struggles. If teaching becomes routinized and we do not help to maintain the life-enhancing qualities of tradition—sources of beauty, truth and freedom—then we are no longer constructively partaking in the unfolding, and making of human history. This is when we become bored and dull, tired and unresponsive" (p. 381). Pursuing transformations in learning contexts invites change for all, including the teacher, and this work should be pursued in the guise of embracing and encouraging a community of support and mutual respect.

There are risks involved when one pursues a transformative pedagogy. Susan Edgerton (1996) pursues different forms of communication in work in multicultural education. Drawing on the work of Michel Serres (1982), Edgerton (1996) situates communication as "the search for sameness but it is necessarily a reaction to and against difference. As such, communication always risks violence (toward that which it excludes)" (p. 57). Similarly, transformative education also risks violence. If one is pursuing change, there are reactions involved. These reactions and responses must be treated with the utmost care and concern. Transformations are in some ways extremely volatile experiences. The community that is involved in changing must have support systems in place and prepared to assist each other in working through these changes.

Drawing on the aforementioned considerations of method and pedagogy, I now pose the two main research questions I will explore in this dissertation. They are:

1) How can complex conversations—those involving multiple perspectives—aid pre-service teachers in becoming reflective practitioners, effective professionals, and inquiring pedagogues?
2) How am I transformed as I experience and reflect on participation in these complex conversations?

These questions involve effort by “teacher” and “student” in which both are learners, knowers and participants. The first question considers why teacher candidates feel they are currently positioned as the student who soon becomes the teacher. The historical situatedness of teacher education and mathematics education become relevant with respect to current epistemological perspectives of teachers and researchers, and these influences are examined in the context of pre-service teachers’ positionalities. Their examination of prior experiences in educational settings set the stage for epistemological and pedagogical considerations of teaching mathematics. In addition, they work the tension between student and teacher, embracing it as part of the conversation rather than fighting and resisting their struggle in this shift.

Embedded within this question is how these complex conversations might influence interpretations for what it means to engage in mathematical instruction. As a class, pre-service teachers and I engage in conversations about psychological learning theories and how they relate to instructional goals and lesson activities. The conversations then turn to hermeneutics and possibilities for moving beyond the limitations of past influences about what it might mean to teach mathematics. In the process, these teacher education students have opportunities for recognizing their own work as scholarly and meaningful, that in fact their opinions do matter.

The second question focuses on my shifting identities and pedagogical considerations as I become transformed by the experiences shared with pre-service teachers, as well as influenced by research in complexity theory, curriculum theory, and teacher education. My "method" is never the same, for what seems a great instructional tool one semester may not match with what occurs in another.[22] Implications of intending a transformative education must be included in my own work. Ethical considerations for what it means to transform are part of this question, for transformative education implies particular judgments and educational perspectives. Overall, my experiences and reflections on particular moments of conversations share how mathematics and teacher education can be conversational, unpredictable, and meaningful for all involved.

Building on the overview of method and pedagogy I provided in Chapter 1, I will proceed in Chapter 2 to outline the historical discourse of teacher education in mathematics, then analyze textbooks currently used in mathematics methods courses. In Chapter 3, I focus on current researchers in mathematics education who have developed alternative approaches to mathematics methods courses. This, in turn, leads to Chapter 4 in which I reveal how my approach compares to those mentioned in Chapter 3, then I answer the research question of how conversations can aid pre-service teachers as they consider what it means to "teach" mathematics. Finally, curricular implications for what teaching complexly involves are explored in Chapter 5.

[22] In fact, those who assume their methods are the same are mistaken. Jut as Hericlatus stated, "No man can step in the same river twice," neither can a teacher instruct in the exact same way more than once. There are so many complex and dynamic patterns that are involved in teaching, the situation is never the same again, not reproducible. One who seeks to teach complexly embraces this perspective.

Chapter 2: Understanding in Education

> *Those who can, do. Those who understand, teach.* (Shulman, 1986/2004, p. 212; emphasis in original)

> …Students frequently memorize by rote rather than acquiring any real understanding or ability to apply the ideas which they remember. (Tyler, 1949/1969, p. 72)

The word understanding is prevalent in current mathematics education literature, as well as in curriculum and instruction in general. In *Principles & Standards for School Mathematics*, the National Council of Teachers of Mathematics (NCTM) (2000b) claims that the curriculum should be "mathematically rich, providing students with opportunities to learn important mathematical concepts and procedures with *understanding*" (¶ 4; emphasis added), and the authors continue to use this term throughout the document. This emphasis on understanding, according to Richard Lesh, Helen Doerr, Guadalupe Carmona, and Margret Hjalmarson (2003), comes from the fact that "much constructivist research in mathematics education has generated careful studies of the nature of the development of students' understanding" (p. 217). Constructivist literature provides examples of student understanding, with such types of understanding as "early understandings" and "mature levels of understanding" (p. 218), and differentiation "among particular states of understanding" (p. 219). Deborah Stepek and Maryl Gearhart (1997) refer to "solid understanding of mathematics" (p. 23), and Miriam Ben-Yehuda, Ilana Lavy, Liora Linchevski, and Anna Sfard (2005) refer to one student having "a higher degree of understanding" (p. 217) than another.

The word understanding may be common in current mathematics education literature, but it has a much longer history. The *Oxford English Dictionary* (1989) defines understanding as the "power of abstract thought; intellect; an individual's perception or judgment of a situation." The root word understand, in verb form, is found as early as the year 888 and interpreted: "to comprehend; to apprehend the meaning or import of; to grasp the idea of." This first definition—"to comprehend"—seems to be the most common interpretation today, but there are many other interpretations found in the *O.E.D.* (1989). One definition, emerging in the 17th century, is "to stand under; to support or assist; to prop up." As early as 1131, to understand also is interpreted: "to have knowledge of, to know or to learn, by information received," which morphed into "to take or accept as a fact, without positive knowledge or certainty" by the 18th century. These other meanings are distinct in their description and reveal a modernist rationale—relying on the assumption that information passes from one to another, often with a sense of that "presumed" or "accepted" by the one who understands "without positive knowledge" or "specific mention."

This slipperiness of the word understand (which constitutes 10 pages in the *O.E.D.*, 1989) appears in the various adjectives often aligned with the word—solid, mature, real, beginning, states of, degrees of, etc., which are cited in constructivist terms by mathematics education researchers above. Furthermore, the dynamics of interpretation are also imposed on the one who is performing the act of understanding—the "understandee"—never questioning the one who determines that understanding has been achieved—the "understander."[23] The use of understanding in mathematics education literature, primarily pertaining to constructivist literature, maintains the power dynamics of knower/learner, something that I believe needs to be questioned and (re)considered. I will begin my exploration by contrasting educational

[23] By using this phrasing, "understandee" and "understander," I am raising the issue of power positions that exist in constructivism. The "understood" in this relationship would be the concept(s) that are being discussed. In constructivism, the teacher is assumed to be the "understander," while the student is situated as the "understandee."

researchers who interpret understanding based on the relationship of "understandee"/"understander" to those who consider understanding as an interpretive act.

In this chapter I engage in such a conversation of how the word understanding is interpreted with respect to mathematics education. Though writing has its limitations in creating complexities, I intend to bring out more questions than answers in the hope of inviting readers to engage in complex conversations with this text. Complex conversations involve openness and open endings, shared experiences, relationships, and dynamical interactions, with transformation as a goal. I begin by highlighting how the word understanding has emerged in educational discourse to reveal ways in which it is used in modern, rationalist ways. I then shift toward postmodern, dynamical interpretations of understanding. In the midst of my pursuit for understanding understanding, I relate this exploration to my research question of how complex conversations can aid pre-service teachers in becoming reflective practitioners, effective professionals, and inquiring pedagogues by weaving in historical, cultural, and epistemological concerns of mathematics education and teacher education. My first section addresses the use of understanding in mathematics education literature, comparing its use as a cognitive, representational act to one that is a contextual, interpretive, and relational conversation. I then outline some of histories of mathematics education discourse, including the current debate of teaching for skills or teaching for understanding. My last section analyzes textbooks currently available for mathematics methods courses as examples of how the rhetoric in mathematics education discourse is translated into teacher education courses.

Understanding in a Modern, Rationalist Frame

The various definitions of the term understanding expose the subjectivity of its utilization and interpretation. In this section, I select the works of James Hiebert and Thomas Carpenter

(1992) and Lee Shulman (1986/2004, 1990/2004) as a way to elucidate how some researchers in mathematics education and teacher education interpret understanding. Their use of language reveals modern, rationalist interpretations that rely on the relationship of "understander" to "understandee." In this interpretative frame, the issue of understanding carries with it the assumption that in the act of "constructing," students acquire a level of understanding, which is assessed by the teacher.

Understanding is a contentious debate within mathematics education, popularly called the Math Wars. Though the Math Wars seems relatively new, the debate has actually been occurring for over a century. As quoted in the epigraph above, Ralph Tyler (1949/1969) questions memorizing versus understanding. Two current mathematics education researchers, James Hiebert and Thomas Carpenter (1992), reference the works of McClellan and Dewey (1895), Thorndike (1922), Brownell (1935), Bruner (1960), and Gagne (1977), to claim that "one of the longstanding debates in mathematics education concerns the relative importance of conceptual knowledge versus procedural knowledge or of understanding versus skill" (p. 77; emphasis added). Hiebert and Carpenter (1992) argue that this debate is asking the wrong question, that it would be better to ask how understanding (concepts) and skills (procedures) are related.[24] They believe that in relating procedures to conceptual knowledge, a flexibility accrues (p. 78). This flexibility is part of Hiebert and Carpenter's (1992) overall view of what it means to understand. They define understanding in an active sense, for the process of understanding is an ongoing act of learning. Understanding, then, is viewed in cognitive terms, as a "process of making connections, or establishing relationships, either between knowledge already internally

[24] Jon Star (2005) argues that the debate of conceptual versus procedural knowledge still exists today, and this dichotomy is revealed in a severe lack of research in mathematics education with respect to procedural knowledge. Star (2005) attributes this deficiency to the superficial definition that procedures implies algorithm and ignore more sophisticated treatments, such as heuristics. In contrast, he would like to encourage more research to be done that would be similar to his idea of procedural flexibility (p. 409).

represented or between existing networks and new information" (p. 80). For them, networks of information are structured as web-like or hierarchical, depending on one's assumption of representation. Either interpretation considers understanding as seeing, developing, building relationships, which are based on theories derived from cognitive science, that there exists a relationship between external and internal representations, and that "internal representations can be related or connected to one another in useful ways" (p. 66). In turn, they focus on useful ways to think about understanding mathematics based on the idea of "connected representations of knowledge" (p. 67). Implementing curriculum based on these assumptions for cognitive development, mathematics educators can focus on how students come to understand.

Hiebert and Carpenter (1992) rely on an interpretation that considers how "networks are constantly undergoing realignment and reconfiguration as new relationships are constructed" (p. 70). Realignment and reconfiguration implies constant revisions and reconstructions, a continuously changing image. With such an interpretation in place, Hiebert and Carpenter (1992) argue that while knowing procedures is part of having mathematical expertise, skill expertise too often encourages efficiency not comprehension. They propose a compromise:

> By thinking and talking about similarities and differences between arithmetic procedures, students can construct relationships between them. In this case, the instructional goal is not necessarily to inform one procedure by the other, but rather to help students build a coherent mental network in which pieces are joined to others with multiple links. (p. 68)[25]

[25] Ted Aoki (1992/2005) provides a different interpretation of thinking. He proposes that Western tradition imagines thinking as cerebral—occurring only above the neck—and leaves no room to "see other possibilities of understanding 'thinking'" (p. 196). Rather than remaining fixed in this limited perspective but not offer prescriptive, dichotomous definitions, Aoki shares stories in order to provide considerations of "thinking that might be understood as thoughtfulness" (p. 196). Aoki writes in poetic prose, hoping to evoke meaning as shared, invited, and open. He asks what *is* teaching and questions notions of being. Humanity is part of the conversation, not just the brain, and thinking becomes thoughtful when considering moments of understanding in contexts.

This suggestion illustrates how Hiebert and Carpenter (1992) assume that procedural knowledge is one aspect of learning that can occur in conjunction with conceptual understanding, rather than having to choose one or the other. They believe this nurtures students' perceptions of mathematics, and teachers can follow the "Learning Principle" from NCTM (2000b), which states that "students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge" ("Overview," ¶ 2).

Continuing what they claim to be a dynamic interpretation, Hiebert and Carpenter (1992) claim that while understanding is a pedagogical goal, instead of occurring in a fixed, linear order, processes for developing this goal are sometimes "manifested as temporary regressions as well as progressions. The changes appear to be intermittent and somewhat unpredictable; students seem to build understanding sporadically, rather than through smooth, monotonic increases," and though acquired chaotically, "ultimately, understanding increases as the reorganizations yield more richly connected, cohesive networks" (p. 69). These relationships do not necessarily progress in a controlled, linear fashion. Networks of connections can occur in recursive and reiterated patterns in which relations are strengthened and understanding deepens.

One significant problem (albeit a modernist one), as stated by Hiebert and Carpenter (1992), is that "if students do not bring with them the kind of knowledge of quantities that teachers expect, it is not easy for students to relate their interactions with the materials to existing networks" (p. 70)—which implies that the "understander" presumes particular expectations. Connecting in relation to others is a part of constructing understandings. These connections are situational, relational, and contextual. So how might teachers accommodate students who struggle to make the connections that are desired by a teacher? Lee Shulman (1986/2004), in a speech given at the 1985 Annual Meeting for the American Education Research Association

(AERA), postulates a specialized kind of knowledge that teachers utilize. His intention is to elevate teachers, one that counters the adage that “those who can, do; those who can’t, teach.” (See the epigraph above.) Shulman (1986/2004) describes a “good” teacher as someone who understands—to understand students, texts, and relations between them. He claims this is displayed with “pedagogical content knowledge” (p. 201). His new category, which is different from content, psychology or pedagogy, is a phrase intended to portray how teachers integrate “the most useful forms of representation, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others” (p. 203). This term also implies a different way of thinking about teacher education. Rather than a prescriptive model, Shulman (1986/2004) argues that pedagogical content knowledge reflects a teacher’s ability to choose wisely what would be the most effective way to engage students in understanding particular subject matter, knowing that this decision is situated within that moment of teaching, a cognitive flexibility—to draw on Hiebert and Carpenter’s (1992) phrase. “Since there are no single most powerful forms of representation,” Shulman (1986/2004) claims, “the teacher must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas others originate in the wisdom of practice” (p. 203). In their wisdom, these teachers reveal that they understand—which Shulman (1986/2004) describes as pedagogical content knowledge.

In another address, this time for the annual meeting of the Holmes Group, Shulman (1990/2004) asserts “Aristotle Had It Right” and passionately argues for liberal education. His argument reveals his proclivity for good liberal pedagogy, along with what he believes is an excellent example of a “good” teacher—one who displays pedagogical content knowledge. This exemplary English teacher is young and new to the classroom, and he is assigned to teach *Julius Caesar* to high school students. Remembering how dull his experience was with this Shakespearian play, he decides to approach the play differently. The teacher searches for a scenario in which he believes his students would have an interest. He decides to connect the character Captain Kirk of *Star Trek* to Shakespeare's Caesar and asks the students how they would behave as members of the crew if Kirk began to act strangely. The class debates the situation, and the students argue what they would do. The next day the teacher makes an analogy between Captain Kirk and Caesar, providing a context for the story. The students have a reference point for their reading, something relevant and shared. Shulman (1990/2004) concludes this vignette with the assertion that this is not the only way to teach *Julius Caesar*, but for this teacher and in the context of his classroom it is a wise choice, effective and potentially rich in connections, a great example of good liberal pedagogy and pedagogical content knowledge. Shulman (1990/2004) generalizes this approach by asserting that

> this young teacher had a very important pedagogical understanding, which is that among the many ways he knew for reading *Caesar*, he had to find some ways, some representations, some "transformations"—in the language of our own research—that would connect with the *understandings*—not the blank slates but the positive, constructed understandings—of a particular group of students. (p. 405; emphasis added)

Throughout this pedagogical moment and in the language of Shulman's work in general, a theme recurs, that teachers can re-present[26] information and knowledge in ways that allow students to connect in meaningful ways. Shulman (1990/2004) counters the belief that students are blank

[26] I choose re-present here instead of represent, for I believe the connotation evokes a different meaning. This move echoes the sentiment of Donna Trueit (2005a), who traces notions of representation in education and their implications for schooling today. See also the work of Deborah Britzman (1997), who questions representation for its limits on what is present and absent (p. 35).

slates with the declaration that understanding occurs when students can relate new information to what they already know or have experienced. Shulman's (1986/2004) pedagogical content knowledge coordinates well with the research of Hiebert and Carpenter (1992), that teachers should focus on student understanding by designing an environment to encourage as many experiences as possible for students to make connections, to create and strengthen networks of understandings.[27]

Understanding in a Postmodern, Interpretative Frame

Hiebert and Carpenter (1992) and Shulman (2004) consider learning to be in flux, but the understandings of the teacher are not questioned—once the "understandee" becomes the "understander." For them a teacher understands if she is able to present or re-present set material in varied ways—to find the most effective way to re-present information. Taking a different approach to curriculum and teaching, William Pinar, William Reynolds, Patrick Slattery and Peter Taubman (1995) present their interpretation of understanding in *Understanding Curriculum*. This text presents some histories and perspectives in the field of education, with each chapter considering what it means to understand curriculum from different philosophical interpretations. In the introduction, they clarify their intention to view the word understand from multiple perspectives, for understanding "invokes issues of interpretation and meaning" (p. 50). Pinar et al.'s (1995) articulation of understanding stems from the perspective that what (we believe) we know is always contextualized and situated, never fixed or universal. Knowledge is the result of a creative act; we understand only in parts, pieces, and only for a fleeting moment, then the moment passes us by, and we wonder if we ever truly understand.

[27] At first glance, this might sound similar to one of Alfred Whitehead's (1929/1967) suggestions, that in order to move away from knowledge as dead or inert, we should let ideas "be thrown into every combination possible" (p. 2). In a closer look, though, Hiebert and Carpenter (1992) focus on a fixed set of strategies, while Whitehead (1929/1967) always sought alternatives, asking, "What else?"

As a more concise way to contrast interpretations of understanding, I have selected two mathematics education scholars, Robert Davis (1992) and Brent Davis (1996). Both of these mathematics education researchers have published works to explore and play with "understanding 'understanding.'" In their publications, they both reference the Pirie-Kieran model (1992, 1994) as a description of students' understandings of mathematics. Their interpretations, however, are quite different. Before I proceed with the dissimilarities of their interpretative frames, I will explain the Pirie-Kieran model (1992, 1994) (Figure 2.1) and how this model relates to understanding in mathematics education.

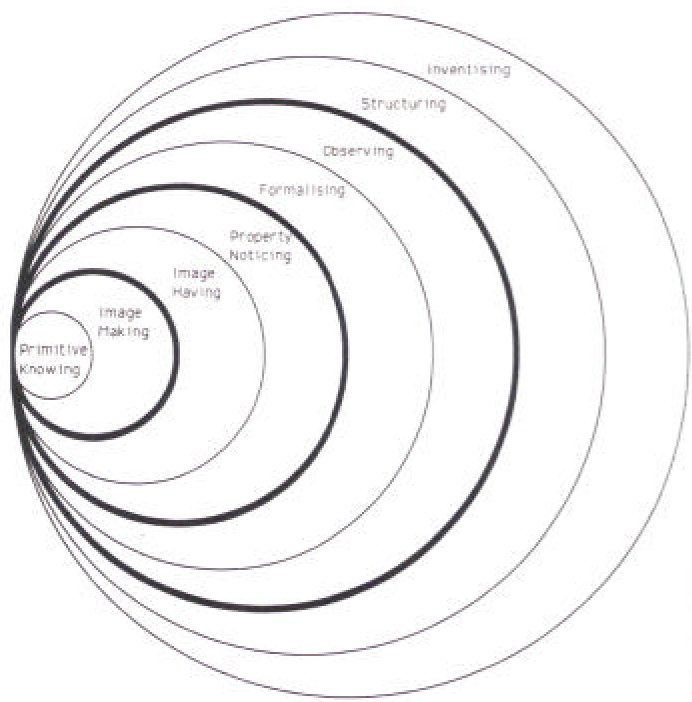

Figure 2.1: The Pirie-Kieran model (1992, 1994)

The Pirie-Kieran model (1992, 1994) is a set of circumscribed circles, depicting different modes of understanding. The circles contain the following categories, from the smallest circle to largest: primitive knowing, image making, image having, property noticing, formalizing, observing, structuring, and inventizing. According to Susan Pirie and Thomas Kieran (1992), these are not developmental stages; instead, the model is intended to convey "a theory of growth of mathematical understanding [that perceives] such growth occurring in the framework of a whole dynamic, leveled but nonlinear, recursive process" (p. 243). Recursion plays a key role in using this model for interpreting student understanding. Pirie and Kieran (1992) strongly oppose an incremental approach. They argue that although their model "contains embedded levels or modes of understanding, it is the dynamic within and between these levels which is critical. We strongly deny any monotonically increasing view of the growth of understanding" (p. 244; emphasis added). Their argument lies in an interpretative frame, one which implies understanding as contextual. Their research includes transcripts of interviews in which different modes of understanding are found throughout the conversations. Their model is intended to assist teachers in paying attention to particular kinds of understandings with respect to mathematics.

I find it fascinating the ways in which Robert Davis (1992) and Brent Davis (1996) interpret the Pirie-Kieran model so differently. Their understandings of understanding are subtle but remarkable. First, Robert Davis (1992) compares what he terms a "previous view" to a "newly-emerging view" in mathematics education. He shows some differences, side by side, to highlight a shift in mathematics education away from algorithmic procedures and towards notions of understanding and of meaning making.[28] His cognitive science interpretation of understanding, similar to Hiebert and Carpenter (1992) and NCTM (2000), is defined as "when a new idea can be fitted into a larger framework of previously-assembled ideas" (p. 228). R. Davis (1992) outlines ways in which meaning making has become important in this emerging form of pedagogy. His interpretations and conclusions resonate with Shulman's (1986/2004) model for pedagogical content knowledge, in that the responsibility lies with the teacher's ability to provide

[28] Meaning making, a phrase used in constructivist literature, implies an individual doing the work. Later I will show how this still sits inside a representationalist frame.

enough examples and situations in order for students to connect their ideas with new information. The stronger the connections, the more understanding that has accrued. The focus remains on the individual student; s/he is the "understandee," the one who is in the process of understanding, who is making connections.[29] The teacher is the one who provides the context for these connections, in the position of "understander."

On the other hand, Brent Davis (1996) employs a hermeneutical and phenomenological perspective.[30] Understanding, according to his interpretation of Pirie and Kieran's (1994) model, is a "dynamic and active process of negotiating and re-negotiating one's world whereby the abstract can never be severed from the concrete" (B. Davis, 1996, pp. 202-203). He argues that beyond a cognitive interpretation, understandings are "relationally, contextually, and temporally specific" (p. 200). His definition considers conversations—complex ones—between and among students and teachers. The responsibility of the teacher, in this frame, lies in the willingness of the teacher to be re-positioned, not as knower but as a significant participant. The teacher is in relation to, not over, the students, and together all are "thinking the world together" in imaginative and exciting ways. This perspective is similar to Pinar et al.'s (1995) notion of collective, momentary, situated knowledge, and in this perspective, knowledge is created, not re-presented by teacher to students. Two significant differences between R. Davis (1992) and B. Davis (1996) are the ability to re-present in various forms versus creative interactions, and B. Davis's (1996) refusal to move to the individual as the sole representative for understanding.

Collective understanding could refer to what I call "we-ness" in Chapter 1. B. Davis (1996) posits it is possible for understanding to occur in the collectivity of the participants, rather than individual comprehension. He writes: "In particular, as [the Pirie-Kieran model] has been

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[29] For an analysis of this situation and some of its difficulties, see Trueit (2005b).
[30] Brent Davis is a former student of Thomas Kieran, at the University of Alberta in Edmonton, Canada.

applied to collective sense-making, the model highlights the manners in which collective understandings do emerge—senses that cannot be located in any of the participants but which, rather, are present in their interactions" (p. 203). Interactions are a significant component of collective understanding. More than strengthening relationships, interactions involve consideration, judgment, listening, all of which are located among and between individuals interacting.

The absence of collective sense-making—a key pragmatist concept—is one particular concern that B. Davis (1996) believes reveals problematics associated with locating understanding only in the individual, as if understanding is some product, an end that can be fixedly attained. This fixed end is a notion held by constructivists, which Brent Davis and Dennis Sumara (2000, 2002) challenge. For example, Davis and Sumara (2002) claim that "metaphors of constructing and building have been seamlessly incorporated into the perspective that learning is a matter of internal representation of an external world" (p. 418). To counter the underpinning of learning as an internal representation, Davis and Sumara (2002) offer alternative philosophies, specifically poststructuralism, psychoanalysis, pragmatism, and complexity sciences, to offer a re-reading of learning and teaching that is not restricted to internal re-presentations of a world "out there." Experiences, interpretations, learning, teaching, epistemologies, all of these are dynamic negotiations that occur in-between, neither yours nor mine, yet both of ours. Here interactions and relationships are vital to creating new moments in which we all understand. Connecting these ideas, I utilize the word understanding as interpreting and making meaning in relational and temporal situations. This notion of understanding embraces relationships as part of the adventure of education, but also honors consideration for how we are always situated, how we can create knowledge and information together, and how we are always in relation. In this frame we can imagine possibilities for new understandings. All students are required to understand mathematics, a national mandate, but what this statement truly means for teachers and teacher educators seems unclear. In this next section I outline the current discourse in mathematics education, and within this discourse I explore relationships between epistemologies (learning theories) and pedagogies (teaching strategies), as well as the use of the word understanding.

Mathematics Education Discourse

As I have shown above, mathematics education researchers pay much attention to student understanding. The NCTM (2000a) “Learning Principle” outlines this perspective: “Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge” (p. 11). NCTM has a long history of reflecting as well as impacting the instruction of mathematics. Understanding became a key concern for mathematics education researchers, which was an underlying influence in the writing of *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). This publication allowed NCTM to make its first step in becoming the governing body for mathematics instruction in the United States, and in the process creating a “national curriculum.” These standards became the unofficial national curriculum for mathematics education, and each state followed NCTM’s (1989) lead by writing its own content standards and curricula based on these *Standards* (1989). While the *Standards* became the framework for what was implemented in the classroom, other scholars (not in mathematics education research) voiced their concerns that the ways in which mathematics should be taught to prepare students for life after compulsory schooling was inadequate. This is when the newest version of the Math Wars began.

Eleven years later, in response to criticisms of the *Standards* (1989), NCTM (2000) published *Principles and Standards for School Mathematics*, an updated version of NCTM (1989) *Standards* that incorporates the references of diverse research perspectives in the principles for teaching as well as content and process standards for mathematics in pre-kindergarten through twelfth grade. The *Standards* (2000) reiterate the original rationale intended by NCTM, as “a professional organization to formally adopt standards: to ensure quality, to indicate goals, and to promote change” (p. 6). By re-writing the *Standards*, NCTM (2000a) offers a “common language” to help shape conversations about mathematics education.

One major difference in the 2000 version of the NCTM *Standards* from the 1989 publication is the way in which the content is organized. The 1989 *Standards* divides mathematics into 13 categories; the 2000 *Standards* separates mathematics into content and process standards, then subdivides each set into five separate categories. The five content *Standards* (2000) include the strands of Numbers and Operations, Geometry, Algebra, Data Analysis and Probability, and Measurement. Each topic is outlined in general terms, then expectations by grade subsets (Pre-K–2, 3–5, 6–8, and 9–12) are given. The five process standards focus on mathematical processes, namely Problem-Solving, Reasoning and Proof, Communication, Connections, and Representation. These are more broad considerations of how students should be processing mathematical content, while the content standards focus on what students should be learning.

In addition, NCTM (2000a) prefaces the 10 standards with principles for learning that include diverse student populations and various epistemologies, blending many voices into one text. These six principles explain in more sundry terms concerns of equity, curriculum, teaching, learning, assessment, and technology than the 1989 document provides. Considerations of multicultural issues, diverse learning styles and abilities, and various epistemological concerns are all addressed, to some extent, within these principles.

According to David Kirshner (2002), the NCTM (2000) *Standards* convey a unified reform agenda that reflects diverse epistemological underpinnings. For example, in the introduction to the *Standards*, NCTM (2000b) provides an eclectic position by claiming: "All students deserve an opportunity to understand the power and beauty of mathematics. Students need to learn a new set of mathematics basics that enable them to compute fluently and to solve problems creatively and resourcefully" ("Introduction," ¶ 3). These two sentences highlight some key terms in current mathematics education, such as understand, basics,[31] fluency, and problem solving. Idealistic in its rhetoric and multi-faceted in its epistemology, the NCTM (2000) *Standards* provide a place for all to feel validated. James Hiebert, a primary author of the NCTM (2000) *Standards*, is also a coauthor of a mathematics education textbook entitled *Making Sense: Teaching and Learning Mathematics with Understanding*. In their book, Hiebert et al. (1997) define understanding as a function of how we can relate or connect an idea to other things we know (p. 4). This definition is reflected in the NCTM (2000b) *Standards*. For example, in the curriculum principle, mathematics is defined as:

> a highly interconnected and cumulative subject. The mathematics curriculum therefore needs to introduce ideas in such a way that they build on one another. Instead of seeing mathematics as a set of disconnected topics, students should perceive the *relationships* among important mathematical ideas. As students build *connections* and skills, their *understanding* deepens and expands. ("The Curriculum Principle," ¶ 1; emphasis added)

[31] Jardine, Clifford and Friesen (2003) argue that "the basics" influence every aspect of curriculum and instruction. "Even more subtle, but far more pervasive, powerful, and diffuse," they claim, "is the use of 'basics' as an often unexamined, incendiary clarion in public discourse and the public press" (p. 3). These authors offer a different set of basics, such as relationships, caring, sharing, conversations, and shared histories. Then they ask the question, "What, in fact, might 'understanding' mean, given this alternate image of 'the basics'?" (p. 3).

The *Standards* highlights relationships and connections as significant for student understanding. Curriculum based on the *Standards* is a "curriculum [that] is mathematically rich, providing students with opportunities to learn important mathematical concepts and procedures with understanding" ("Introduction," ¶ 4). By "rich," the authors of the *Standards* imply creating an environment in which provides students with the potential for many connections, because as defined earlier, the more the connections, the deeper the understanding.[32]

Developing curriculum that focuses on understanding does not mean that teachers should avoid working through proficiency of basic skills, according to the NCTM (2000) *Standards* [which we know is a sentiment of Hiebert's from his work with Carpenter (1992)]. The language of the *Standards* conveys this pragmatic tone, and NCTM (2000b) believes that the *Standards* "describe the basic skills and understandings that students will need to function effectively in the twenty-first century" ("Introduction," ¶ 8). Including skills and procedural knowledge in the NCTM (2000) *Standards* is an attempt to appease those who are proponents for what is "mathematically correct," while not leaving out those who believe in conceptual development. The "Mathematically Correct" group is part of a "back to basics" movement that is involved with the mathematics education establishment (NCTM) in an ongoing debate, called the Math Wars. The "war" erupted after the publication of NCTM's (1989) *Standards*, what critics call "New-New Math" or "fuzzy math."[33] The incorporation of skills and procedural knowledge in the language of NCTM's (2000) *Standards* demonstrates in part how influential this backlash has become. Though Hiebert and Carpenter (1992) have asked mathematics educators to consider

[32] William Doll (1993) offers a different perspective for a "rich curriculum." I share his definition in Chapter 4 as I explore what it means to teach complexly.

[33] A new group has emerged, aiming their accusations directly at NCTM. Their web site is entitled: "Ten Myths about Math Education and Why You Shouldn't Believe Them" (Budd et al., 2005). Jay Matthews (2005), a staff writer for the *Washington Post*, invited NCTM to reply to each of the 10 myths and has published the myths, the statements by Budd et al. (2005), members of NYC HOLD (Honest Open Logical Discussions), and NCTM's responses to these "myths" as counterstatements.

procedural and conceptual knowledge in tandem, the debate still continues. Advocates on each side are determined that their interpretation of “the basics” is better for mathematics education.

Math Wars

The Math Wars are an ongoing feud between those who support the traditional approach (memorization) to mathematics education and those aligned with the reform approach (construction). Often it seems that the language in use is, at best, compatible. For example, both sides of the war claim a desire for understanding. Though they share this word, the meaning behind how they use it is quite different. The word concept is another that appears continuously, but the underlying implications are not the same. The debates in the Math Wars address epistemological notions for mathematics, though the attacks are not limited to theoretical issues. They encompass a broad scope of educational concerns, such as textbook and curriculum adoptions, assessment, performance, school board decisions, standards issued by local, state and federal institutions, and pedagogical practices.

Before I examine pedagogical practices in mathematics teacher education courses by analyzing some textbooks, I provide an overview for the position of each side of the debate. The two camps for this controversy are entitled “Mathematically Correct” (the traditionalists) and “Mathematically Sane” (the reformists). Outlined below are the distinguishing characteristics for each group. The key debate is essentially the diverse acceptance for how students come to know, for student understanding. Jerry Becker and Bill Jacob (2000) critique the countless accusations aimed at the NCTM (1989) *Standards*: “Content knowledge is no substitute for knowledge of how students’ understanding develops, but this point seems lost on these critics” (Becker and Jacob, 2000, p. 536). Advocates for both sides of the debate proclaim their desire to teach what is best to the students and in a manner that is “most effective.”

Those claiming to be *Mathematically Correct*—Mathematics professors, physics professors, parents and others—join together in the fight for a "back to basics" method for teaching mathematics. Algorithms and repeated practice are among the "essentials" needed for mathematics achievement. This conglomerate feels that mathematics instruction today is neglecting "the systematic mastery of the fundamental building blocks necessary for success" (Mathematically Correct, 2004). They assert that learning new skills requires prerequisite skills, and as these are perfected, new skills can be attained.

Recent events in California and Massachusetts elucidate an overall objective for this organization. In an interview with a reporter of the *Boston Globe*, one member states that "Mathematically Correct objected, in part, to the lack of much traditional computation—getting examples of how to solve a math problem and then practicing it by doing several more—in the California curriculum" (Downs, 2000, p. C5), and uses this as a justification for supporting a return to traditional methods in Massachusetts as well. Those concerned with a more traditional approach embrace teaching methods used in the 1950's as exemplary and the way to teach math, by repetition and memorization.

In contrast to the traditional approach, reform mathematics emerges from different research methodologies and theoretical notions of learning. The *Mathematically Sane* group was created as a response to promoters of more traditional methods and from the desire for educators to "provide an alternative—and more accurate—view of reform by making a compelling case that changes in our nation's mathematics programs are imperative for our students' future success" (Archer, Hoff, and Manzo, 2001, p. 10). Conceptual development and metacognition are among the underpinnings for reform mathematics. Furthermore, this group espouses innovative techniques that focus on gaining student interests, communicating mathematical concepts, relating to “real world” problems, and encouraging students to believe they can do math.

In an attempt to eliminate the repeated attacks by the “back to basics” group, the “fuzzy math” group claims that “the present standards say memorization and traditional computation have not been dropped from the curriculum, just de-emphasized in favor of children understanding how math works” (Downs, 2000, p. C5). In this context, the use of understanding connotes meaning-making, and R. Davis’s (1992) understanding concurs that newly emerging practices reveal this focus. Reform mathematics is prevalent in many schools today, and the standards issued by NCTM (2000) affect (or should I say, dictate) many states’ standards that continue to determine the path of mathematics education, which means conceptual understandings are to be a part of the curriculum. Furthermore, the National Science Foundation financially and politically supports this movement. These words may sound kind, but, in fact, they are a condescendingly futile attempt to appease the traditional drill and practice approach. The NCTM (1989, 2000) *Standards* are intended to be a suggestion as to what conceptual goals the teachers, schools and departments of education should aspire. However, many educators take them as doctrinal truth and build their programs in kind, not de-emphasizing but eliminating (Wu, 1999).

Not to advocate any particular viewpoint or leave out any perspective, the NCTM (2000) *Standards* include perspectives for those who are on both sides of the debate, whether it is conceptual understanding or procedural knowledge. For example, the first content standard is “Number and Operations.” In this section, advocates on both sides of the Math Wars could be appeased by the following statements: “Computational fluency—having and using efficient and accurate methods for computing—is essential.... Computational fluency should develop in tandem with understanding" (NCTM, 2000b, "Numbers and Operations," ¶ 3).

Pragmatically incorporating the language of both sides of the "war" seems to appease neither side. Proponents of the "back-to-basics" movement are more vehemently protesting "experimental" methods than when the movement first began. The educational act, *No Child Left Behind* (2002), exemplifies this perspective. Ironically, though one of the main arguments of Mathematically Correct is that expectations have been lowered due to the reform movement, the legislation of *No Child Left Behind* mandates that schools prove *all* students are successful at a basic level (Ryan, 2004). By focusing the attention on "guaranteeing" that all students perform well on standardized tests, schools are limiting their options to employ diverse methods due to the consequences that might ensue based on student performances, thereby lowering their expectations and creating a mediocre learning environment.

Harold Schoen, James Fey, Christian Hirsch, and Arthur Coxford (1999) defend the reform movement, supporting the initiative to "make important and broadly useful mathematics meaningful and accessible to all students" (p. 446). These authors attempt to placate the debates in the math wars by discussing "balanced" curriculum, based on the *Standards*. What they fail to mention is the perspectives of the authors who wrote the *Standards*, as if the standards are an objective document that holds no subjective position with respect to mathematics. The language of the NCTM (2000) *Standards* gives reference to skill acquisition, but the references are slight and pedantic. Skills are dismissed by researchers in search of conceptual understandings. Hung-Hsi Wu (1999) calls this a "bogus dichotomy," that it must be either skills or concepts. As an alternative, Wu (1999) offers skills and concepts as interconnected that can work together to enrich learning mathematics.

In Chapter 1, I shared the story of my students walking the Cartesian plane. The skill of "plotting" points was one objective, but there was another rich moment that occurred later in the class for which I would not, could not, have imagined or pre-determined. I had offered my students a bonus assignment of answering the question of how imaginary numbers can be applied in "real" life. (This was a question that emerged amidst a discussion of number systems, and it appeared a genuine question on the part of the students.) One student, Amanda, shared her conversation with a friend who is an engineer. When she asked him about applications for imaginary numbers, his response was that she would not understand his answer, even if he told her. This upset me, so I decided to share one way in which I understand imaginary numbers, because I believe she could understand.

Before the activity of walking the plane, my students presented a mathematical lesson or activity that related to a children's book. Casie shared her idea of a treasure hunt in which students were given the time of day (as a directional angle—my words, not hers) and number of steps (for magnitude) in order to find the buried treasure. I connected these concepts, angle and magnitude, to the Cartesian plane that was still taped on the floor, and explained my personal connection—understanding—between Casie's activity and imaginary numbers.[34] I physically stood at the origin facing the positive *x*-axis, turned in a counterclockwise direction, and took a few steps in that direction to demonstrate my explanation.[35] The entire class seemed excited about the connections. Amanda's response was, "I understand what you are saying; why couldn't

[34] I wonder if Shulman (1986/2004) would consider this a moment that reflects good "pedagogical content knowledge."
[35] This is merely one example of how imaginary numbers can be expressed. There are many others forms that can be used to express imaginary numbers, as well as explained.

my friend just say it that way?" The class then speculated as to why he refused her, and the possibility of whether he truly understands imaginary numbers.[36]

Though the war continues, researchers and teachers alike are trying to find ways to alleviate the controversies through epistemological blendings and compromises. This is most obvious when reading the NCTM (2000) *Standards* with both perspectives in mind. In his assessment of the current situation in mathematics education, Kirshner (2002) distinguishes among learning outcomes and uses them to categorize learning theories, and in doing so, contradicts, what the reform movement, sponsored by NCTM, tries to convince educators is good pedagogy in general.[37] Kirshner (2002) highlights the "distinctive and contradictory qualities of 'good teaching' [to] emphasize the need for teachers to resolve difficult values issues and then to devise *their own syntheses* in case they opt to pursue multiple learning objectives" (p. 50; emphasis added). His crossdisciplinary strategy is significant for educators who feel pressure for students to not only achieve success on high-stakes tests (skills), but also conceptual understanding and socioculturally appropriate dispositions.

Kirshner's (2002) creates his "crossdisciplinary framework based on metaphors of learning as habituation (informing behaviorist and information processing theories), conceptual construction (informing Piagetian constructivist learning theories), and enculturation (informing sociocultural theories)" (p. 49). Through these three distinct metaphors, Kirshner (2002) argues, "learning is seen to progress very differently in these three conceptions" (p. 50). Within a habituationist frame, learning is perceived as gaining skills. From a constructivist perspective, what is acquired is conceptual understanding. An enculturationist agenda seeks to attain

[36] This shift in conversation, and a critique of the engineer's statement, I believe exemplifies how mathematical knowledge in a relationship of power dynamics. For a more in-depth analysis, see Walkerdine (1988, 1998). She examines and questions knowledge production and relationships.
[37] In Chapter 4, I explain how I use Kirshner's (2002) crossdisciplinary strategy and encourage pre-service teachers to consider it.

particular sociocultural dispositions. Kirshner (2002) provides what he deems good pedagogical examples, not because they are exemplary in practice but because of “their unifocal aspiration toward the specific learning objective” (p. 50). By providing precise examples for each of the metaphors, Kirshner (2002) is able to convey his distinctions among them.

His intent is not to keep these categories separate but to enable teachers to recognize to what ends their pedagogical strategies are accomplishing. The use of the word crossdisciplinarity encourages educators to incorporate the different notions of learning, but with the knowledge that each has its own outcomes and to be prepared to deny one if another is more important. Kirshner (2002) intends for crossdisciplinarity

> to marshal the best possible guidance for teaching supported by the discrete notions of learning that psychology, in its fragmented diversity, thus far has succeeded in coherently articulating. This positions teachers to consult their own values, interests, and strengths in defining their own teaching priorities, highlighting the special difficulties faced in opting for multifocal learning objectives. (p. 55)

Highlighting these discrete notions of learning provides a context within which an educator can choose a strategy, or more than one. Within this framework, Kirshner (2002) is not trying to create a new learning theory or suggest that one of his three categories is somehow better than the other. One could interpret that Kirshner (2002) remains within a rationalist, representationalist frame, but I would argue his strategy is his way of making sense of the various psychological learning theories that have been researched for many years and how they influence pedagogical decisions.

Kirshner (2002) provides an example of a teacher who feels she must “‘walk … the pedagogical tightrope’ (Wood, Yackel, and Cobb, 1995, p. 421) between her concern for students' intellectual development and her concern for their social development" (p. 52). This is a dilemma that many teachers face because they do not expect to have to choose, for somehow "diverse learning objectives always can be seamlessly meshed in good teaching" (p. 52). This argument is founded on Kirshner's main criticism of the reform movement in mathematics education. Rather than continue in the current path of "blended" epistemologies, Kirshner (2002) provides, via the crossdisciplinary strategy, an opportunity to "change the tone and tenor of reform toward a true innovational movement whose rallying cry is educational efficacy rather than orthodoxy" (p. 55). This statement initially caught my attention, which I have been mulling over for quite some time. In working through his words, I consider his comparison of efficacy (capacity or power to produce a desired effect) to orthodoxy (a belief or orientation agreeing with conventional standards). I believe there is much truth to this comparison. Teachers often engage in "band wagon" ideas. Constructivism seems to be the most popular ideology currently in education.

The use of manipulatives is also prevalent in mathematics textbooks, while the reason for this is often unknown to the teachers who believe they must include them if they are to be perceived as innovative (Wheatley and Reynolds, 1999). Kirshner (2002) proposes the crossdisciplinary strategy as a way to challenge the continual adaptation of "new" approaches to what may be considered the conventional epistemology. Teachers should consider what is the most effective for their learning objectives, and as they determine to which epistemology they believe, their objectives should be prioritized.

Mathematics Methods Textbooks

In Chapter 1, I raised the issue that pre-service teachers have the expectation that I will present to them the way to teach mathematics. Along with this expectation is the assumption that a mathematics “methods” textbook will accompany me in this endeavor. From where do these expectations and assumption come? I believe their assumptions and expectations derive from my students’ experiences in traditional mathematics education. These pre-service teachers expect to know the way to teach mathematics by the end of our semester together.

In the remainder of this chapter I explore a selection of commonly used mathematics methods textbooks in the United States. By analyzing these texts and their influence on the discourse of mathematics education, I intend to reveal how my students’ expectations stem from their experiences in mathematics classrooms in which teachers rely on the epistemologies underpinning the language of the authors of these methods textbooks. Specifically I seek to find what kinds of conversations these texts are encouraging. I obtained current textbooks designated for elementary mathematics education by requesting a desk copy from various publishers, with the intent of analyzing what type of conversation(s) these authors encourage. The books were selected for their relevance to this inquiry, as well as their availability. They are typical of texts used in elementary mathematics education courses and reflect the discursive practices within the tradition. Six of the textbooks are similar, more traditional in format and presentation, and I call these “conventional” textbooks. In addition, there are four textbooks that are “unconventional,” not for their similarities to each other but because they all differ significantly from the more traditional group. In all but one of these textbooks, the authors exhibit modern, rationalist ideas in mathematics education rhetoric

In each of the textbooks, the authors claim to present “new” ways of teaching mathematics and argue their interpretation is the best way, whether that way adheres to a particular epistemology or blends and integrates various interpretations. The underlying assumptions, however, seem to fit within a modern, rationalist frame. In order to situate my analysis of these textbooks as modern and rationalist, I will first explain my interpretation for these terms. One curriculum theorist and mathematics education researcher, Jayne Fleener (2002), outlines the works of Galileo Galilee, Rene Descartes and Isaac Newton as the 17th century thinkers upon which the foundations of modern physics, philosophy and mathematics were established. “Their emphasis,” Fleener (2002) claims, “was on objectivity, theory, abstraction, rationality, and certainty, which are cornerstones of the modern mind-set” (p. 20). Following this mind-set, Fleener (2002) defines the basic tenets of modernism “as an emphasis on scientific reasoning and individual rationality, an assurance in universal truth, and a certainty in social progress” (p. 20). Scientific proof is deemed valid, maintains a rational logic, and carries a universality that omits situation, context, and multiplicities.

William Doll (1993) also examines the modern, rationalist frame that emerged in the 17th century. Doll (1993) focuses on the traditions of modernity that are evident in education today. He asserts:

> It is Newton’s metaphysical and cosmological views—not his scientific ones—that have dominated modern thought so long, providing a foundation in the social sciences for causative predictability, linear ordering, and a closed (or discovery) methodology. These, in turn, are the conceptual underpinnings of scientific (really scientistic) curriculum making. (p. 34)

Doll (1993) highlights key terms, such as causality, predictability, linearity, and closed systems. According to Doll, as well as Fleener (2002), a modern, rationalist frame entails an assurance that scientific methods will hold true, no matter the context or situation. Modern, scientific methods adhere to the notion that replication is possible, assume language is universal, and maintain predictability based on cause-effect relations. These notions are prevalent in the discourse of mathematics education, and I suggest these characteristics of modern rationalist thought, embedded in educational practices, shape pre-service teachers' expectations of what it means to teach.

Conventional Texts: Multiple Perspectives, Convergent Paths

A quick glance at mathematics education textbooks confirms that understanding remains a primary focus in mathematics education. Looking more closely, there are particular ways in which mathematics education researchers have translated their perspectives of understanding into textbooks for future teachers. I provide an analysis of some of these texts as a way to explore how the rhetoric of mathematics education researchers reveals the authors' modern, rationalist tendencies, as evidenced in their suggestions for what qualifies as "good" teaching.[38] This analysis is intended to reveal a distinction between rhetoric and reality. Although the rhetoric suggests engaging in conversations, the reality is that the conversations are not complex. The discourse is one-sided and quite modernist. The authors are concerned with specific ways to teach by telling, assume language is universal, and maintain predictability based on cause-effect relations.

This section focuses on six texts I classify as "conventional" textbooks. (Table 2.1 provides an overview of these.) They follow a similar format of defining mathematics, offering a range of learning theories, and focusing the remainder of the text on ways in which a teacher can effectively teach specific mathematical concepts. Sample lesson plans, student work, and assessment strategies accompany these suggestions. The other four texts are different from the more typical type of text. Each of the "unconventional" texts targets a singular learning theory as an epistemology and expands upon connections to mathematical instruction. By looking at all ten textbooks, I hope to show the extent to which the concept of conversations in these texts is one-

[38] As an interesting twist on this phrase, see Doll, 2005, on "teaching good."

sided and unilateral, as well as to raise the issue of how complex conversations can occur in mathematics education discourse, discussing differences that make a difference.

Table 2.1. "Conventional" Textbooks

Author(s)	What is Math?	Metaphor	Epistemology(ies)
Hatfield et al. (2005), *Mathematics Methods for Elementary and Middle School Teachers*	structures of thinking in conceptual, knowledge packages (p. 3); culturally relevant mathematics (pp. 19-28); emergent mathematics (p. 128)	develop *knowledge packages* for mathematical concepts (p. 3)	“complexity of mental structures, ‘Learning is Action;’ ...theories of information processing and their diversified ways of storing and retrieving information in the brain, ‘Learning is Process’” (p. 45)
Kennedy, Tipps, & Johnson (2004), *Guiding Children’s Learning of Mathematics*	the tool we use to reason through everyday problems (p. 4)	*well-balanced* variety of teaching interactions (p. 87)	behaviorism and cognitivism (constructivism, information processing, and brain research) (p. 29-37)
Reys et al. (2004), *Helping Children Learn Mathematics*	“1) a *study of patterns and relationships*; 2) a *way of thinking*; 3) an *art*, characterized by order and internal consistency; 4) a *language* that uses carefully defined terms and symbols; and, 5) a *tool*” (pp. 1-2)	*patchwork quilt* offers opportunities for connections (p. ix); process of building bridges (p. 24)	constructivism (Piaget, Vygotsky); behaviorism (Skinner)
Sheffield & Cruikshank (2005), *Teaching and Learning Mathematics: Pre-Kindergarten Through Middle School*	patterns is key to the nature of mathematics; a science of patterns (p. 4)	math is not a mystery but an example of pattern and structure (p. 13)	constructivism (Piaget); brain research
Troutman & Lichtenberg (2003), *Mathematics: A Good Beginning*	"unified system and language, not merely a set of isolated topics" (p. 74)	integrate *windows of learning* to create as big a view as possible (p. 22)	12 fundamentals based on research by Piaget, Vygotsky, Skinner, Steffe, and "brain-based"
Van de Walle (2004), *Elementary and Middle School Mathematics: Teaching Developmentally*	*"the science of pattern and order;"* "science of things that have a pattern of regularity and logical order" (p. 13)	learning is connecting the dots (p. 23)	constructivism (Piaget, von Glasersfeld)

Implicit in the modernist frame is a particular relationship between teacher and learner. The teacher should understand both mathematical content and student conceptual development; therefore, the authors provide directives for future teachers about facilitating and nurturing students’ conceptual and procedural developments. Within this frame, conversations are not encouraged. Discussions, directives, intended objectives are the focus of these texts. One group of authors assert that “teachers need to understand what constitutes procedural and conceptual knowledge and the importance of helping students make connections and establish meaningful relationships between them” (Reys et al., 2004, p. 22). Once a student is able to re- present mathematical concepts, then the teacher believes the student has learned, has acquired understanding, and the teacher is successful—a good teacher. Martin Heidegger (1945/2002) argues, “In the university, where logic and argument prevail, the pedagogical relation between teacher and student is understood in homologous terms as a practical instance of the more general relation of subject to object” (p. 34). This approach is passed down, from instructor to pre-service teacher, from teacher to student. Though the teacher has a repertoire of activities and manipulatives, the teacher is still the knower and the student remains the learner. These are examples for what Trueit (2005b) describes as “practices of modernity: the individual, viewing the world as object, analyzing it in reference to his (her) perspective and pronouncing upon it” (p. 95). This description presents one interpretation for what it means to understand: replication.

Another aspect of these textbooks that reveal a modern, rationalist frame is the authors' defining mathematics. The intended audience of these books—pre-service teachers—have had many years of experience in mathematics classrooms and time to form their own opinions for what mathematics is. This does not seem to be acknowledged, however, in any of the texts. By defining mathematics, the authors of these texts are trying to create a particular way of conceiving math, which I believe reveals a modern, rationalist frame in which mathematics, like language, is assumed to be precise, to convey meaning, and to explain a logical and fixed reality.[39] This is similar to the first step of Descartes' method, to begin with what is clear in one's mind (see Chapter 1), as if this goal is attainable, and even if it is, as if the language that one speaks clearly communicates an idea in one particular way. One of the NCTM (2000a) process standards, communication, contains the description that "instructional programs should enable all students to… use the language of mathematics to express mathematical ideas precisely" (p. 402). The belief that language can be precise and effectively communicate a mathematical idea is a modernist ideal. The way in which communication is viewed is important. In contrast to Brent Davis's (1996) suggestion for hermeneutical listening in which participants in a conversation do not have intended agendas but are actually listening and considering others' comments (see Chapter 3 for more description), communication as described by NCTM (2000) is about repeating already known ideas in precise ways. This form of communication does not encourage complex conversations but rather discussions and mimicry.[40]

Within this set of texts, the one group of authors who come closest to acknowledging that language is constantly reinterpreted is Mary Hatfield, Nancy Edwards, Gary Bitter, and Jean Morrow (2005). Unfortunately, they argue for culturally relevant mathematics by essentializing ethnic groups and "their" ways of learning and cultural experiences. Hatfield et al. (2005) qualify culturally relevant mathematics as a "term that shows awareness on the part of educators that mathematics exists within a cultural environment" (p. 19).[41] The problem is that their argument includes examples of how Native American, African and Latin cultures—as if there is one homogenous culture for each group—approach learning from a more holistic view. This line of

[39] Ludwig Wittgenstein (1958) questions the notion that a word carries a particular meaning. He counters this belief with the idea of language games, which implies that language is an interpretative act that is constantly in negotiation. I expound upon this idea more, with its relevance to mathematics education, in Chapter 3.
[40] Davis (1996) contrasts conversations with discussions, which I describe in detail in Chapter 5, in the context of complex conversations.
[41] This interpretation, that mathematics is not an isolated subject but is created in cultural and historical contexts, is an idea with which I agree, and I expound upon how mathematical curriculum theorists consider culture and mathematics in Chapter 3.

reasoning follows well with Donna Trueit's (2005b) definition of modern, rationalist thinking, that there is an objective "other" to explain. The authors attempt to support their argument by singling out contributions made by researchers who are members of "those" cultures, specifically mathematicians who are able to achieve success in white, Western, European mathematics. Therefore, everybody can learn to perform mathematics this (correct) way. The authors' intent seems sincere, but their acknowledgement of "cultural diversity" is restricted to a modernist interpretation of culture, language, and relationships. They remain in a closed system that suggests that if we do math this way, we will soon all be mathematicians.

To reiterate this point, that we all can do mathematics, let us look at John van de Walle's (2004) *Elementary and Middle School Mathematics: Teaching Developmentally*, the most widely adopted elementary mathematics education textbook in the United States. Van de Walle (2004) believes "there is absolutely no excuse for children learning any aspect of mathematics without completely understanding it" (p. 14). He defines understanding as "a measure of the quality and quantity of connections that an idea has with existing ideas. Understanding depends on the existence of appropriate ideas and on the creation of new connections" (p. 24). The justification for his interpretation lies within the psychological learning theory of constructivism, which he believes can help teachers "stop teaching by telling and start letting students make sense of the mathematics they are learning" (p. 14), for "constructivism provides us with insights concerning how children learn mathematics and guides us to use instructional strategies that begin with children rather than with ourselves" (p. 22). This strategy still encourages an imitation and re-presentation of skills and tasks. Teachers need to be clever in the methods they use that "trick" students into thinking the right way.[42]

[42] Brent Davis (2005) describes historically how the word "right" has come to mean "correct" in our current language, and that this interpretation is based on a modernist, rationalist logic of precision.

Understanding, in this frame, implies students knowing what has already been established. In mathematics education today, there is little argument about what mathematical content should be taught, instead of focusing on ways to interact. Van de Walle (2004) claims that the work of Jean Piaget and other developmental psychologists helped shift "the focus of mathematics educators from mathematics content to how children can best learn mathematics" (p. 1). The issue of content over pedagogy has become obsolete since the combination of the NCTM *Standards* (2000) and *No Child Left Behind* (2002). Content is predetermined.[43] Van de Walle (2004), as well as the other authors, focuses the majority of his book on relating mathematical concepts to students. Questioning what should be taught in a mathematics classroom is never introduced. The focus, in light of a constructivist agenda, is assisting students in conceptual development through activities that allow students to share their personal understandings so the teacher can intervene and redirect as needed. Many examples of students' misunderstandings are provided so the teacher can know what to expect. Assumptions of predictability and cause-effect relations underlie this discourse, which hinders opportunities for complex conversations. If a student says a particular statement, here are some ways to assist the student and redirect. When a student does this, a teacher will know what that student is communicating. Learning becomes predetermined, predictable, a pattern of differences that a teacher can easily recognize so as to create situations in which a different activity, a new manipulative, or another explanation will cause a different effect—understanding.

With this perspective in mind, Hatfield et al. (2005) instruct pre-service teachers to consider the significance of understanding how students learn:

[43] In Louisiana, the Department of Education has issued the *Comprehensive Curriculum* in which teachers follow what is to be taught on what day. I critique this curricular approach in Chapter 5.

> Understanding the developmental nature of how students learn and construct their own mathematical knowledge will help you plan more effective instruction for those students entrusted to your care. This must be done in light of new research and best practices coming from brain research. It is possible to analyze students' ability to do quality mathematical thinking when presented tasks that correspond to their individual unique ways of learning. (p. 45)

These authors convey a common belief in mathematics education, that there are such things as best practices,—"what works"—and teachers can determine students' individual ways of learning. Such certainty, based on "brain research," reasserts Fleener's (2002) claim that a modernist ideal is "the belief that, through rational, dispassionate, objective, replicable means, universal truths can be found, sets a value on the kind of knowledge most worth having" (p. 23). In this modernist discourse of mathematics education, teachers must be prepared with a repertoire of examples and effective methods so as to "pass on" what is known.

These textbooks reveal a belief in the validity of scientific method, which maintains a modern, rationalist frame. The authors perpetuate the idea that imitation implies understanding, transfer of understanding is possible, universal truths exist without question, and students are predictable in how they learn, based on cause-effect relations. As such, "the curriculum, based in the modern paradigm, similarly reflects and perpetuates the oppressive framework of value-hierarchical thinking, value dualisms, and the logic of domination" (Fleener, 2002, p. 47). In light of the analysis, I examine four other textbooks that are more unconventional in their approach. By contrasting these four textbooks, I show that even though the authors of the conventional texts attempt to shift the discourse of mathematics education, they are still trapped within a modern, rationalist frame. I focus on the uniqueness of these alternative texts, not for their similarities to each other but for their differences in contrast to what would be considered a typical textbook for a mathematics education course.

Unconventional Texts: Singular Focus

The six "typical" textbooks are similar in language, format, and promote the type of text of an elementary mathematics methods course that is expected and widely accepted as the "norm." To offer alternatives, I have chosen also to analyze four textbooks that are different, on many levels. These four books are not what an instructor would "typically" choose when adopting a text for an elementary mathematics methods course. Nonetheless, these texts are potential candidates, and as such, I examine them as a way to provide alternatives for traditional texts. First, these authors refrain from demonstrating how to teach specific mathematical content by topic, a typical organizational structure for the conventional texts. Second, each text focuses primarily on one particular epistemological perspective. Table 2.2 gives a list of the four texts, alphabetically by author, along with their epistemological perspective and primary focus for the book.

Table 2.2. "Unconventional" Textbooks

Author(s)	Epistemology & Focus
Borich (2004), *Effective Teaching Methods*	The author focuses on overall teaching strategies that are effective for multiple disciplines. He separates direct from indirect instruction, and he compares them as respectively behaviorism and constructivism.
Hiebert et al. (1997), *Making Sense: Teaching and Learning Mathematics with Understanding*	Cognitive psychology with its emphasis on internal mental operations, and social cognition with its emphasis on the context of learning and social interaction; focus is on not conforming to a single method of teaching but instead considering a system of instruction within a specific context (p. 14)
Ronis (1999), *Brain-Compatible Mathematics*	Brain-based research (Caine & Caine); focus is on performance tasks that fulfills the brain's innate search for meaningful learning (p. 32)
Wheatley & Reynolds (1999), *Coming to Know Number: A Mathematics Activity Resource for Elementary School Teachers*	Enculturation; focus is on teaching as negotiating and considerations of classroom culture (p. 26)

All of the other texts previously discussed as well as the ones that follow focus on elementary mathematics education classroom, with the exception of one. Gary Borich (2004) focuses on how to teach any subject in the elementary classroom. His text offers generic methods, and he focuses on overall teaching strategies considered effective for multiple disciplines. He separates direct from indirect instruction, and he compares them as behaviorism and constructivism, respectively. There is little room for conversation; the tone of the text is a "how to" manual. While antiquated in many of his suggestions, his ideas seem to resonate with much of the arguments in the Math Wars by those who are calling for "back to the basics." Instruction should be focused on assisting students in determining the "right" answer. The teacher is the provider of knowledge and students are blank slates. Content, whether in mathematics or any other subject, is not considered, questioned, or debated. Instead, how students best learn facts, skills and procedures is clearly outlined. This text is very narrow in its epistemological scope and offers little assistance to teachers and students alike.

The second unconventional text, *Brain Compatible Mathematics*, by Diane Ronis (1999), follows what has been termed "brain-based" research. Ronis's (1999) primary concern is to create what she terms as relevant, performance tasks. She defines learning as developing connections between neural networks (p. 3) and elucidates what she considers "brain-friendly" tasks. Her text contains sample unit tasks that she claims fit within this frame. "The relevancy of performance tasks," Ronis (1999) asserts:

> fulfills the brain's innate search for meaning. The open-ended nature of these tasks allows for a variety of learning styles and multiple intelligences to flourish, and the low-stress,

> highly challenging classroom environment encourages the development of the kind of meaningful learning that the brain craves. (p. 32)[44]

If a teacher uses particular tasks to accommodate various learning styles, then meaningful learning can occur. This author's position reflects a growing movement in educational literature, particularly the notions of “brain-based” research, multiple intelligences, and learning styles, and Ronis (1999) in particular seems to focus on performance tasks that are “brain-compatible.” While this rhetoric appears post-modern, like its claims of an “open-ended nature,” the frame within which this perspective functions is actually a modern, rationalist frame. According to brain-based research, thinking occurs in the brain, isolated to connections of neurological processes. Science “validates” this perspective, but what validates science? I believe that along with the idea of “brain-based” research is the belief that mathematics exists objectively, apart from humankind, just waiting to be discovered (see Chapter 1). Conversations are deliberate, focused on how the teacher can reach each student individually. Though Ronis’ (1999) text offers a different format in that she is unifocal in her epistemology, in her vision of how one comes to know, I believe her activities and arguments are similar to the more conventional textbooks in her perpetuation of “teaching as telling.”

In contrast to these two texts, Hiebert et al. (1997) adhere to the belief that teaching is not a single method but a system that is contextually bound. I have placed this book in the “unconventional” section because this group of authors uniquely creates a diverse collection of research projects rather than presenting in unison how to effectively teach mathematics. They provide a collaborative, introductory chapter, but then diverge into various projects in which some of the co-authors are researching. In addition to their menagerie of mathematics education

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[44] Ronis (1999) draws solely upon Renate and Geoffrey Caine for her justification for “brain-based” pedagogy. I believe this line of research is limiting and restricts imagination and ingenuity.

research projects, I believe the authors deliberately omit chapters that are devoted to specific mathematical content. In lieu of this typical format, various research projects in which mathematical content is a part of the discussion, along with student samples, are provided. These projects are not intended to be models but vignettes for how students can learn mathematics with understanding. The authors align their work by agreeing on a common goal, namely that "students need flexible approaches for defining and solving problems. They need problem-solving methods that can be adapted to new situations" (p. 1). The authors also believe there should be a focus on relationships. As a reiteration for what constitutes understanding and how it can be developed in mathematics, Hiebert et al. (1997) claim that "understanding is built through establishing relationships: relationships between what one already knows and new information, relationships among different ways of representing information, and relationships among different methods of solving similar problems" (p. 101). Epistemologically similar, locally different, these projects present a conglomeration of mathematical communities that are intended to resist the urge for teacher as authority and shift the focus of knowledge ownership to the individual learner. They believe their position encourages students to develop flexible problem-solving skills, which nurtures their abilities to be creative in methods when presented with new tasks. This book is an example of an unconventional textbook because it follows a different format, with the intention of communicating ways in which individual teachers can facilitate a classroom culture focused on student understanding in localized ways.

While Hiebert et al. (1997) shift the rhetoric in their text toward more open-ended, contextualized ideas, they still maintain that the responsibility lies with the teacher's ability to provide enough examples and situations in order for students to connect their ideas with new information. The focus remains on the individual student and the belief that a teacher can “correctly” ascertain at what point a student now understands. This remains within the modern, rationalist frame of positioning the teacher as knower and student as learner, instead of considering how texts change as communities engage in conversations around ideas within and beyond the scope of the text.

The last book moves away from a modern, rationalist frame and considers a postmodern, dynamical approach. Grayson Wheatley and Anne Reynolds (1999) provide an alternate “method.” Their focus is primarily on problem solving and how students can explore mathematical ways of thinking without the pressure of learning algorithms and procedures. They define mathematics as “an activity of constructing patterns and relationships” (p. 2), more than just a set of rules, and they consider this as different from the more mainstream definition, which they believe focuses on the “process of acquiring knowledge that involves memorizing facts and procedures” (p. 2). The text is brief and written in a conversational tone as a way to facilitate conversations around what Wheatley and Reynolds (1999) believe are misnomers in mathematics education. One particular topic is the use of manipulatives in mathematics classrooms. Most elementary classrooms now integrate manipulatives in the instruction of mathematics, but the motive is more due to the concession that the use of manipulatives implies a good mathematics program, rather than how they can assist students in conceptual understanding. In fact, a “manipulative activity can be just as procedural as using a subtraction algorithm” (p. 24), which belies the intent of manipulatives in mathematics education. The assumption that as long as a teacher is using manipulatives “understanding” must be occurring for students is prevalent in the other textbooks listed above. Consideration for how manipulatives should be integrated is not presented, which appears to be true in the education community at large. Wheatley and Reynolds (1999) challenge this assumption in the hope that teachers will consider how to effectively use manipulatives.

Mathematical content is not presented by Wheatley and Reynolds (1999) in the format of "teaching as telling." Like Hiebert et al. (1997), Wheatley and Reynolds (1999) avoid grouping mathematics into categories (like the NCTM (2000) *Standards*); instead, they provide ways to engage students in conversations about mathematical ideas that allow for open-ended conversations about concepts, not limiting students (or teachers) in one particular direction. In fact, their text is contained in less than fifty pages. The remainder of Wheatley and Reynolds' (1999) book is a set of black-line master sheets that can be used as activities in an elementary mathematics classroom, with no script or prompt for teachers to follow directly. The teacher is encouraged to facilitate conversations and encourage students' ideas in creating and imagining mathematics together.

This text is emerging as a new and resourceful contribution to the field. In a personal correspondence with me, Grayson Wheatley shared that their text is being adopted in Toronto and sales in the last year have increased to over 4,000 copies. This number is close to the number of sales reported by two of the texts in the "conventional" category. In contrast, the publisher of Diane Ronis' (1999) textbook refused to provide for me the number of texts sold, claiming this to be "private information between publisher and author." I wonder if this response echoes with Ronis' (1999) prescriptive approach to teaching, which does not leave room for negotiation and conversation, part of functioning within a modern, rationalist frame. Maybe as teachers begin to use texts that are similar in spirit to Wheatley and Reynolds' (1999) conversational book, pre-service teachers (and mathematics teacher educators) might change their expectations to no longer look for “how to” manuals that provide certainty and instead look for books that nurture relationships and inspire conversations.

The four unconventional texts given are not a homogenous group. They are quite diverse in their epistemological interpretations, pedagogical strategies, and rhetoric. The first two, Borich (2004) and Ronis (1999), move toward an extreme of laying out exactly how a teacher can present information in clear, precise ways that “guarantee” success—understanding—without ambiguities. These two texts are similar to the set of conventional textbooks with that goal in mind. Hiebert et al. (1997) offer a different approach from all of these by claiming that the work of educators involves local, contextual, meaningful approaches that are not generalizable. Their words offer inspiration to teachers to devise their own ways of teaching. Wheatley and Reynolds (1999) go even further by offering ways to engage in conversations in which all participants are significant contributors and that knowledge and learning is always changing, always in flux. I believe these last two texts offer potential for encouraging complex conversations with pre-service teachers that move away from prescriptive models toward emerging interpretations and understandings.

(Mis)Understandings

By providing an analysis of mathematics methods textbooks, I have demonstrated how educators still fall into the misconception of presenting mathematics, albeit creatively, interactively, and visually, as what is already understood. This perpetuates the myth that teaching mathematics involves giving students ways to linearly solve particular mathematical concepts without allowing for students’ thinking to be “messy,” to challenge, question, struggle, and create. As a way to answer the second part of my first research question, how these complex conversations influence their interpretations for what it means to teach mathematics, I now shift from understanding to questioning. Complex conversations include asking questions, not questions to which one already knows the answer, but questions that are asked in the spirit of community relations which nurture complex conversations.

My first move is to historicize mathematics and consider its sociohistorical contexts and developments. There are particular problematics about “doing” history, which I interrogate as a way to contextualize my research. Issues of gender and hegemony in mathematics emerge from doing a history of mathematics, and I follow with a feminist analysis of these problematics. Rather than choose one particular critique, I open up the conversation to different categorical distinctions of these issues and articulate how all can inform different perspectives of mathematics and mathematics education. I conclude this section with questions about learning to teach and teaching to learn, in hopes of engendering mathematics in complex ways. Then I shift the focus to the works of educational researchers who consider mathematics contextually. I place them in conversation with each other as a way to explore mathematics and the basics, mathematics and culture, and mathematics and language. In particular, I highlight Brent Davis, M. Jayne Fleener, Valerie Walkerdine, Peter Appelbaum and D’Umberto Ambrosio as alternative mathematics education researchers. Drawing on their respective works, I relate these explorations to what their research might offer in terms of understanding, connecting to what types of learning emerge in light of these different perspectives, and how these changes challenge current assumptions in teacher education.

Chapter 3: Alternative Perspectives in Mathematics Education

Questioning is the piety of thought. (Heidegger, 1954/1977, p. 35)

In a speech I heard, the presenter repeated the phrase, "Please understand…." I interpret this statement to mean, "Please agree with me." To understand in this frame is to comply or concur with what the speaker is asserting. In contrast, complex conversations involve understanding, not compliance but shared understanding through community relations. Complex conversations include asking questions, but not questions to which one already knows the answer. This is different from current mathematics education discourse, as shown in Chapter 2, for the questions in the current discourse assume the teacher must already "know" everything before engaging in instruction. Furthermore, the current discourse conveys more concern with accomplishing objectives and agendas and less concerned with emergent learning. Specifically in mathematics education, there is an assumed "correct" answer, which leads to instruction that is focused on obtaining necessary skills and understandings so as to perform correctly. The current discourse in mathematics education is not a complex conversation. So what might a discourse that nurtures complex conversations encompass?

One particular aspect in considering how complex conversations can influence interpretations for what it means to "teach" mathematics is the notion of questioning. Martin Heidegger (1954/1977) posed the idea that "questioning is the piety of thought" (p. 35). The *Oxford English Dictionary* (1989) defines *piety* as "habitual reverence," "devoutness," and "dutifulness." I believe that Heidegger (1954/1977) is challenging the manner in which we question, that we should be devoted to thinking and that we have a duty to think. This perspective could greatly influence what kinds of conversations are occurring in classrooms (from elementary to secondary to higher education). If complex conversations do not function in the same way as "teaching-as-telling," then questions in a complex conversation will emerge differently than those in the mode of knower/learner (or "understander"/"understandee").

The mode of "teaching-as-telling" is not synonymous with constructivism, for in constructivism, the role of the teacher is to ask questions, to work alongside the student, and to ascertain conceptual understandings and misunderstandings. How complex conversations differ from a constructivist pedagogy is the focus of learning. Constructivism is completely student-centered; learning occurs within the student. The role of the student is to do, to perform, to question, to suggest understandings. The teacher's role is to ask, to question, to hypothesize and test their assumptions about student understandings, then to question more. In this process, the teacher is constantly making judgments about the interpreted understandings, and how best to next question the student so the student might obtain a better conceptual understanding. These judgments rely on the teacher's ability to conceptualize, and this form of interaction allows the teacher to maintain the role of "understander," while the student is the "understandee." This modernist, rationalist dichotomy of either teacher or student, either understander or understandee, is problematized in complex conversations; the distinction becomes blurred. Complex conversations allow for a continually (re)negotiated set of interactions, and the location of what is understood is always present in the system, not located in the individual. So while constructivism is different from the mode of "teaching-as-telling," I believe it is still located in a modernist, rationalist frame in which the roles of teacher and student remain fixed, where the teacher remains in control.

Recently, I listened to a group discussion of first grade teachers with an instructional specialist. The teachers were requesting that their mathematics textbook company provide them with instructions on how to use the textbook in their classrooms. To me, this does not convey the mindset that these teachers believe they have a duty to think. Underlying their request is the idea that if someone else tells them how to teach, then they can, in turn, follow directives. Someone else knows “what works.” Teaching should not be about following directions but about being involved in a learning environment, one in which all are learners. The teachers’ request, I believe, is in direct contrast to my first research question, which inquires as to how teachers might be(come) reflective practitioners, effective professionals, and inquiring pedagogues. Complex conversations, even in first grade, can occur in ways that allow teachers and students to be reflective. In complex conversations, the roles of teacher as “knower” and student as “learner” are transformed into everyone asking questions to which they may not know the answer. In this sense, “the question does not *follow* learning; it precedes it. It points to the not yet known and to the wondrous” (Davis, 1996, p. 253). This mode of questioning is different from the “guess-what-I’m-thinking” mentality that occurs in the interactions associated with the “knower/knowee” mode. It even goes beyond the constructivist notion of “guess-what-the-student-is-thinking” mentality. This follows with William Doll’s (1993) assertion that in an open, self-organizing system, “teachers need student challenges” (p. 159) in order to create, transform, and learn. Questions are not disruptions; they are necessary for living systems to grow. Understanding, then, occurs as we cooperatively struggle with questions/issues, ones John Dewey called “real problems.” As both teachers and students, may we be inspired by Dewey’s “real problems” and Doll’s (1993) pedagogic creed, to work on “reflecting on the tacit understanding each has” (p. 160).

Keeping real problems and reflective pedagogy in mind, one particular question should follow all questions: What is the intent of the questioner? In the first part of this chapter, my intent is to question the manner in which mathematics is historicized. Margaret Wertheim (1997), in her book *Pythagoras' Trousers,* is concerned about the history of mathematics and science. She shares who is portrayed in the limelight and who is left completely out of the picture. In her analysis, she reveals the underlying "maleness" of rationality and reasoning, which includes mathematical reasoning. This translates into a dominant conversation that assumes mathematics is a fixed body of knowledge, in which the teacher is the knower. Teacher questions in this frame are not invitations to explore; they are rhetorical devices designed to have the student mimic the teacher.[45]

The first section in this chapter also includes questions concerning the field of mathematics. The questions raised by various researchers reveal their penchants toward particular issues associated with mathematics education. By raising my own questions and repeating the questions of others, I intend to show how mathematics education continues to perpetuate the mentality of "knower/knowee," instead of encouraging wonderment and exploration of the not-yet-known. How educators envision mathematics is how mathematics is taught.

Subsequently, I present some ideas in the works of mathematics educators who are asking open-ended questions. Charles Lucas (1997), in his synoptic text of a history of teacher education in the United States and its ensuing reform movements, follows a brief history of methods courses with a section entitled "Alternative Views." I find merit in his proposition that "a teacher preparation program should afford opportunities for teacher candidates to involve themselves in the work of sustained reflection and critical analysis" (p. 126). I take this idea further by highlighting the work of international and national theorists whose could be classified

[45] These types of "discussions" (Davis, 1996) are what Donna Trueit (2005a) refers to as mimetic devices in which "representation is *imitative*" (p. 79).

as “alternative” in the sense that they critique “basic” assumptions of mathematics education. These education researchers include Peter Appelbaum (United States), Ubiratan D’Ambrosio (Brazil), Brent Davis (Canada), M. Jayne Fleener (United States), and Valerie Walkerdine (Australia). Drawing on their respective works, I present questions that emerge as challenges to current assumptions in teacher education courses. I think all of the listed researchers would agree with Ludwig Wittgenstein (1958), who said that his intent in writing is not “to spare other people the trouble of thinking. But, if possible, to stimulate someone to thoughts of his own” (p. iv, in Fleener, 2002, p. 163). As educators, we should be open to questions, both in asking and in answering. Questioning is part of our duty to think.[46]

Methods of teaching mathematics implicate societal beliefs about what is mathematics and perceptions of the value of mathematics in society. As I explore the notion of method, especially as it pertains to mathematics education, I delineate the role mathematics has played, and beliefs about what is mathematics, in modern society. In Chapter 1, I outlined a brief history of method and the shift from the dialogical, linguistic tradition led to written, textbook-driven pedagogical practices. Included in this historical analysis was that idea that while there is a common belief that mathematics provides an assessment of an objective reality, mathematics is actually a human endeavor. Now I elucidate how mathematics has long been a man’s pursuit, only to the degree that men have espoused their mathematical discoveries and, as in Wertheim (1997), how women are in the story but not in the picture.

Historical Perspectives

> There is no permanent, finished, and absolute knowledge either in time or in cultural space. (Walkerdine, 1990, p. 23)

[46] This group of mathematics education researchers is by no means exclusive. I have selected them for my own interests in their challenges, questions and intellectual meanderings.

I believe pursuing the notion of method and its historical implications in educational history is a worthwhile venture; however, a problem lies in “doing history.” The notion of history itself contains problematics that feminists explore. Petra Munro (1998) takes the position she claims is contradictory, of simultaneously doing history and being suspicious of it. She maintains that this task is worthwhile, for “we must become comfortable with a more complex, less tidy, nonlinear understanding of the history of curriculum theory which disrupts the very categories that make ‘history’ intelligible” (p. 264). Donna Haraway (2004) positions herself similarly, proclaiming that social feminists risk seeking out so much difference that the “confusing task of making partial real connection” can get lost. “Some differences are playful; some are poles of world historical systems of domination. ‘Epistemology’ is about knowing the difference” (p. 20). Interrogating systems of domination within the field of mathematics while exploring its history is a complex task that could disrupt the categories so nicely created by those considered arbiters of mathematical knowledge and education. I separate historical texts into two groups, traditional and critical histories. Within each group, summaries and limitations of these texts are provided as a way to complexify what could be considered a history of mathematics.

Mathematics as His-Story

The field of mathematics is more than just numbers and symbols. Mathematics is an ideology, a repertoire of argumentation justified within its own internal logic. Alongside the developments of theorems and concepts, there exist historical texts that share stories of intellectual growth in the field of mathematics. These historical texts share similar delineations of the history of mathematics in the world from the earliest recorded civilizations.

For example, Louis Karpinski (1925) highlights the mathematics of the Egyptians, then the Greeks and Romans, focusing next on the Hindus and Arabics, moving then to the

Europeans, and concluding with the Americans. The second half of his *History of Arithmetic* dwells on specific mathematical concepts and their historical developments. One example he gives is the concept of the number zero, which can be found in the works of Greeks and Babylonians but was formally introduced as a number by the Hindus (p. 41). Karpinski (1925) seems convinced of the importance of learning the history of mathematics, claiming that "to understand the progress of arithmetic in America is to understand more fully the whole history of the New World" (p. v). What Karpinski fails to mention in his text is the limited rendering of history that he performs, never expressing a desire to complicate the conversation. He mentions neither female nor male, as if somehow those involved in the development of mathematical concepts are androgynous. Furthermore, Karpinski (1925) makes no mention as to the social status of those he is describing. In only one instance, he refers to a slave as a pedagogue who "accompanied the child to and from school. Both in Greece and in Rome elementary instruction including numbers was frequently given by such a slave. However, the teacher of arithmetic and more particularly of geometry enjoyed a higher status" (p. 169). He does not problematize these positions of knowledge and power; instead, he perpetuates the stereotypical understanding that mathematics is performed by men who enjoy a position of privilege. As Chris Weedon (1998) points out, defaults in our language are quite telling. Through Karpinski's failure to address gender or privilege, he reveals his defaults, and I believe defaults that are common in our modern society, that mathematics is a male-dominated activity, involving those who are in a position of privilege. By questioning the defaults in our language, we can begin to examine how our language isolates and objectifies others, as well as to move forward to engage in more inclusive—not convergent—and complex conversations.

Decades later, another mathematician, Morris Kline (1962), published his first text of a history of mathematics, *Mathematics: A Cultural Approach*. He claims to have created a textbook for liberal arts students to capture the "beauty" of mathematics without the intimidation of procedures. He writes:

> No techniques are taught for the sake of techniques because technique *per se* is worthless knowledge and is not utilized later in life by the nonprofessional. The proofs of trigonometric identities are not important, but the fact that trigonometry has given man his understanding of the heavens is important. Let us cease teaching scales to students who do not intend to play mathematical sonatas. In general, mathematical literacy, by which I mean understanding, is worth far more than technical proficiency. (p. v)

His goal of achieving mathematical literacy is framed through an historical overview of mathematics, followed by definitions of mathematical terminology and how they relate to general knowledge, such as literature, art, and science.

While admirable in his intention to write a mathematical text that encourages students to embrace a perspective of mathematics as a journey of wonder and discovery, Kline (1962), like Karpinski (1925), maintains a gender-neutral presentation in his history of mathematics, well depicted in his argument that the "primary objective of all mathematical work is to help man study nature" (Kline, 1962, pp. 4-5). His male-dominated, Eurocentric perspective is pervasive throughout the text. Though Kline's (1962) text is entitled *A Cultural Approach*, his definition of culture maintains the traditional generic idea of a society situated geographically and historically, without a further analysis of sociocultural or gender dynamics within that culture.

More than twenty years later, Kline (1985) writes another text of mathematics history. This one is entitled *Mathematics and the Search for Knowledge*, and his work seems to reveal a more sophisticated analysis of the history of mathematics. Kline (1985) states that “science can no longer confront nature as objective and humanity as the describer. They cannot be separated” (p. 226). Though the influence of perspective of mathematics and science as an absolute has been affected by the development of quantum mechanics, in which absolutes are replaced with probabilities, Kline (1985) still maintains mathematics as the language of nature.[47] Kline (1985) concludes his grasp of a mathematics of probabilities by claiming that “our mathematics may be no more than a workable scheme. Nature itself may be far more complex or have no inherent design. Nevertheless, mathematics remains the method par excellence for the investigation, representation, and mastery of nature” (p. 227). Walkerdine (1994) argues that this position of dominance and power over nature needs to be questioned, interrogated, even rejected. She proclaims:

> The dominance of the grand meta-narratives of science is deeply caught up with a European bourgeois project about power and dominance and has nothing to do with nature, but that the idea of nature was itself manufactured and intimately connected with the deep and minute processes of government. I am suggesting therefore that we need to move beyond such meta-narratives, towards a model of thinking as produced within practices that are themselves historically and culturally located. (p. 70)

Further, she argues from a post-structural perspective that we should interpret knowledge as information situated historically and socio-culturally. Kline’s (1985) text concludes with an introduction to a new branch within science, namely quantum physics. Consideration of sociocultural situatedness is an important “method” that indicates a significant break from an objective presentation of events in a linear, time-dependent frame.

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[47] Charles Sanders Pierce (1992) claims, “All the great mathematicians whom I have happened to know very well were Platonists” (p. 284, fn 6). Not all mathematicians think of mathematics as Plato did, *i.e.* representative of some transcendental (universal) reality. I explore this idea in relation to teaching mathematics in Chapter 5.

In response Kline's (1985) limited cultural approach, I would like to raise a question as one way to complexify the conversation of a history of mathematics. Who is "our" in our mathematics? Assumed is the Eurocentric perspective, not an acknowledgement of one limited perspective of mathematics. Many different cultures exist, with their own mathematical understandings, axioms and theorems. The lineage of the Greek's mathematics that continues in Europe, along with some influences of "other" (as in non-Christian, non-European, non-bourgeois) cultures along the way is the historical frame of this text. This analytical frame is not stated but rather presented as the way to consider the progress of scientific thought.

Consider an alternative perspective. Ubiratan D'Ambrosio (1985) assumes an anthropological approach to mathematics. He coined the term *ethnomathematics* as a way to situate his research within mathematics education and anthropology. D'Ambrosio (1985) considers different ways of knowing mathematics, for "mathematical developments in other cultures follow different tracks of intellectual inquiry, hold different concepts of truth, different sets of values, different visions of the self, of the Other, of mankind, of nature and the planet, and of the cosmos" (p. 15). He continues his thesis twelve years later, more vehemently arguing that mathematics is part of a Western hegemony pervasive in Eurocentric intellectual histories. The colonization of the world by Europeans remains somehow absent in presentations of histories of mathematics and science, and D'Ambrosio (1997) points to the fact that the "globalization that occurred after the sixteenth century was the decisive factor in the development of modern science and mathematics, carrying with it the ideology of superiority and predestination intrinsic to the Mediterranean religious traditions" (p. 14). He maintains that this superiority still exists today. For example, when he discusses the Asian mathematical concept of male and female triangles, this idea generates laughs among the audience. Why? D'Ambrosio (1985) argues that this occurs because the Eurocentric way of "knowing" mathematics is a dominant ideology in America, and other ways of knowing are considered secondary.

In contrast to Karpinski (1925) and Kline (1962, 1985), Phillip Davis and Reuben Hersh (1981, 1986) present a more conversational approach to "doing a history" of mathematics. They write short chapters that are thematically structured and playful in tone. Their overarching question addressed in both books is summed up in this statement: "So there is mathematics, and there is the history of mathematics and the mathematical experience. They may be linked through the question: are the truths of mathematics independent of time?" (Davis and Hersh, 1986, p. 196). The two mathematicians argue that the "truths" of mathematics are, in fact, contextually bound within history and experience. The narratives are different from more traditional texts in their recognition that mathematics is not a fixed, established way of knowing, but rather a subject that progresses, like all other content areas.

Though Davis and Hersh (1981, 1986) seem to be unique in their approach, they still present mathematics as a history of men. This narrow approach to history of mathematics and science has not gone unnoticed. Many scholars have taken up the task of "righting/writing" history so as to reveal the limitations of this approach and its implications in society.

Mathematics as Her-Story

Mathematics has historically been perceived as a gendered endeavor. Women, as argued above, are absent from the dominant, traditional histories of science and mathematics. As a response, female researchers have produced alternate narratives within mathematical discourses as a way to speak to the inequities that exist within science and mathematics. These narratives can be categorized in four ways: 1) Inequities—gender inequity in mathematics and how "we" might resolve the dilemma of these disproportionate representations of females in mathematics, starting in secondary school (e.g., Fennema and Sherman, 1976; Fox, Brody, and Tobin, 1980); 2) Validities—women have different ways of knowing and should be acknowledged as valid knowers (e.g., Harris, 1997; Pasztor and Slater, 2000); 3) Histories—histories of women who have been excluded from historical texts (e.g., Grinstein and Campbell, 1987; Cooney, 1996); and, 4) Commodities—analyses of the production of mathematical knowledge and how this influences sociocultural perspectives (e.g., Keitel, 1986; Walkerdine, 1998). Separately, these approaches to the gendered history of mathematics can be limiting, but together they produce a rich discourse of research that (re)positions mathematics as subjective, rather than objective, and situated, rather than universal through time and space.

Inequities

Disproportionately, women are underrepresented as professionals and scholars in the fields of mathematics and science in America today. Elizabeth Fennema and Julia Sherman (1976) are considered pioneers in developing a mode of inquiry, as creators of the *Fennema-Sherman Mathematics Attitude Scale* that is still used today, to measure the effects of women's attitudes about mathematics. Lynn Fox, Linda Brody, and Dianne Tobin (1980) find gender inequity in mathematics, from secondary schooling all the way to the professional level. They present arguments in quantitative form to justify their arguments for why there are not more women in mathematics. In conjunction with their research, they suggest ways in which women could become a more significant part of mathematics discourses.

True, women are underrepresented in mathematics and science. But by trying to force women to consider how they might become part of the mathematical world, these researchers leave unquestioned why this is a societal struggle. There are, however, other frames which consider some underlying reasons for gender inequity. As long as mathematical ideologies remain unquestioned, the power and control of mathematical inquiry remains in the hands of the dominant class. D'Ambrosio (1997) refers to the "seemingly unchallengeable position of mathematics" (p. 14). Walkerdine (1990) argues that other content areas "reveal the dynamics of cultural exposure, of mutual influences in the evolution of ideas. But the expansion and absolute imprint of science is unchallenged" (p. 21). The belief that mathematics is a universal language, free of ideology and subjectivity is being challenged. This is not a new perspective. Kline (1985) summarizes Wittgenstein's argument about the subjectivity of mathematics when he shares that "mathematics is not only a human creation but is very much influenced by the cultures in which it was developed. Its 'truths' are as dependent on human beings as is the perception of color or the English language" (p. 222). Mathematics is not an absolute, fixed set of truths, but a body of knowledge that is continually (re)conceived and (re)produced as society continues to change.

The argument that there needs to be improvements for the representation of women in mathematics, while valid, is only part of the story. As a field, mathematics is not void of biases and needs generally to be (re)considered as a subject.

Validities

A second category within the realm of women and mathematics is the argument that women have just as valid ways of knowing mathematics as men do. This contention draws upon gender difference that is "equal-but-different" (Walkerdine, 1998, p. 159). One British female mathematician, Mary Harris (1997), argues that though mathematics is perceived as a masculine activity and quilting as a feminine activity, in fact quilting has many mathematical concepts embedded within it. She presents her analysis at conferences with a quilt in hand. She argues that there are many approaches to mathematics and processes in which people come to "understand" mathematics, just as a quilt can be made in different ways. The quilt serves as a metaphor for displaying patterns as well as a method for the instruction of mathematical concepts.

Harris's (1997) approach is only one example of ways in which researchers try to justify that the process of learning mathematics does not have to be framed within what is considered "valid proofs," the kind usually found in textbooks. A difference between Harris' (1997) common threads and D'Ambrosio's (1985, 1997) *ethnomathematics* is the notion of validity. Harris (1997) maintains that the abstract, academic mathematics can be found in feminine practices as well as in masculine activities. In contract, D'Ambrosio (1985) questions the body of knowledge of "academic mathematics" and focuses instead on a different form of knowledge production, one that is *a posteriori* rather than *a priori*. D'Ambrosio (1997) does not claim to situate ethnomathematics within academic mathematics; instead, he proceeds to move beyond Western mathematics itself. Therefore, the argument that women do just as much mathematics as men, and that should be acknowledged, falls short of a more holistic critique of the hegemonic influences that exist within the validation of what it means to know mathematics.

Also within this category can be found research in which women's ways of knowing are different from men's, creating an essentialist perspective of gender. Ana Pasztor and Judith Slater (2000) present their experiences of emotional imbalance caused by a conflict between "their identities and beliefs and their capabilities and behaviors in their working environments" (p. 328). They claim that as scientists they must perform in certain ways, while as women (mothers, wives, etc.), they must choose a different performance. Pasztor and Slater (2000) assert that a woman's way of knowing is through relationships and people, while a man's way is through ideas and things. Their argument parallels Harris' (1997) in the claim that academic mathematics is considered a masculine endeavor. Unfortunately, Pasztor and Slater (2000) fall into the same trap of trying to create a “separate but equal” argument that does not work. Esssentializing gender, then placing men and women as distinctly different in their approach to mathematics, fails to recognize the fluid categories of gender (see Anzaldúa, 1987; de Lauretis, 1990; Gilmore, 1994).

Histories

I do not deny gender inequity should be a concern in mathematics and science, nor do I claim that there are not other “valid” ways of knowing. What I do suggest is that these arguments are, in and of themselves, only limited interpretations of problems within mathematics. A third aspect is the presentation of women who have succeeded in mathematics and science, produced as counter-narratives to other histories of science and mathematics. For example, Louise Grinstein and Paul Campbell (1987) edit a collection of essays that presents biographic information of over forty women who have contributed to the field of mathematics. Included in these essays are the works and references of mathematicians and scientists who also are women, and whose stories are often not included in historical texts. Miriam Cooney (1996) also presents a set of stories about women who have been successful in mathematics and science. These books share information about women who should be included in mathematics history books.

While the authors present remarkable mathematicians and scientists, who happen to be women, and their texts are great resources for untold stories, the authors do not investigate why these women have not been included in “traditional” texts. To reread Karpinski’s (1925) history of arithmetic and his historical text concerning the Greeks after reading about Hypatia in Grinstein and Campbell (1987) is to begin to recognize that there are gaps in the histories of mathematics and science.[48] How much more is left untold? One could argue an uncountable amount of information is not shared, for as humans we are limited by our perceptions, of what we conceive as reality. Going back through historical texts that attempt to present mathematics and science as gender-neutral while simultaneously conveying only stories of men reveals a glaring neglect of a potentially more inclusive, engendered history. This revelation generates an imperative for researchers to investigate why women have been noticeably absent from historical narratives of mathematics and science. This leads to the fourth research category, where knowledge production is considered a gendered activity.

Commodities

"Knowledge is Power" is a colloquialism often used, though what this phrase truly means is obscured by its use to inspire individuals to learn. Whose knowledge is power? In what ways can knowledge be used as power, as a commodity? These are just a few questions to examine assumptions that lie beneath this statement. Rather than continue in similar patterns of analyzing gender dynamics within the already existing discourse of mathematics, some researchers use a poststructural method of analyzing mathematics as a body of knowledge that is gendered. One such poststructuralist is Valerie Walkerdine (1988, 1990, 1994, 1998). She argues that girls are being "counted out" of mathematics, and her poststructural analysis "does not lead to an equal-but-different conclusion at all, but to one of gross inequality: an oppression produced out of a complex mixture of fact, fiction, and fantasy" (Walkerdine, 1998, pp. 159-160). Mathematics is oppressive? She argues that it is not the mathematics that oppresses but those who *use* mathematics who oppress. Walkerdine (1998) does not believe patriarchy and capitalism to be a "monolithic force which imposes socialization on girls. Rather, we are interested in the processes

[48] I describe elsewhere (Smitherman, 2005) that fractals can provide a nice image for revealing uncountable sets of holes while still maintaining a structure. The Cantor Set is one such fractal, revealing holes and wholes (p. 174). History might be imagined as the Cantor Set; while some stories are shared, there are always more untold stories.

through which the modern order, patriarchal and capitalist as it is, produces the positions for subjects to enter" (pp. 163-164). There is a need to examine the revered position of mathematics in society and how mathematics is used to subjugate certain individuals. This investigation should include considerations of inequities, validities and commodities in the discourse of mathematics. This sentiment echoes Catherine MacKinnon's (1987) feminist perspective that "what counts as truth is produced in the interest of those with power to shape reality, and that this process is as pervasive as it is necessary as it is unchangeable" (p. 137); a reality of inequity is the mixture of fact, fiction and fantasy.

In another approach to answering the question of knowledge production, Christine Keitel (1986, 1989) explores how mathematizing the world has created a perception of reality, which she terms as a creation of a second nature that reconstructs the first, "exclusively admitting objective, mathematical laws, devaluing the authority of individual and collective (subjective) experience or insight" (Keitel, 1989, p. 9). She claims that this creates a disparity of experiences for students between lived and academic mathematics. Because academic mathematics is considered as the valid way of knowing and doing mathematics, students must learn how to perform this way and acknowledge that their practical experiences may be irrelevant.

Walkerdine and Keitel seem to share what Munro (1998) claims is a feminist poststructural reading of history, in which she moves to

> disrupt the search for origins and to decenter the unitary heroic subject, either male or female. [Further, she] also want[s] to challenge the myth of progress by conceiving of history as the confluence of processes so interconnected that it cannot be reduced to a single unitary storyline (grand narrative). (p. 263)

The interconnectedness of his-stories and her-stories are explored in Walkerdine (1998), Keitel (1989), and D'Ambrosio (1985). These works reveal the entangling of multiple stories of histories. By revealing the arguments as well as the limitations of traditional and alternative texts, I argue that the histories of mathematics as interconnected and entangled and that do not reduce mathematics to a unitary storyline but rather open up the dialogue for multiple perspectives

Learning to Teach/Teaching to Learn

Rather than conclude this section with stories and critiques that offer a binary of a feminist method (as opposed to a patriarchal method), I would like to open up the conversation to engage in complex interactions of texts that consider what it might mean to learn to/and teach mathematics. Following Donaldo Macedo and Lilia Bartolomé's (1999) lead, I recognize it is important to "develop a lucid clarity regarding the interrelationship between learning and teaching in order to realize that there is no teaching without learning and that learning ultimately determines and shapes teaching" (p. 119). I postulate coupling mathematical knowing with lived experiences and open-ended questions of exploration. My objectives do not include encouraging girls to perceive themselves as capable in mathematics nor to hope for an increase in the number of women who professionally choose a career in mathematical or scientific careers, though I think these are both worthwhile aspirations. My purposes are to nurture an alternative perspective of mathematics, as a study of investigations of patterns rather than a memorization of truths, and to challenge current and prospective teachers to consider how mathematical "truths" keep happening, in the hermeneutical sense. Within this frame, the concept of methods becomes transformed into a more hermeneutic endeavor—open, nonlinear, and dynamic.

Constantinos Tzanakis and Abraham Arcavi (2000) argue for the inclusion of history of mathematics in mathematics courses; for studying history could produce different perspectives for what it means to do mathematics. I concur that the integration and presentation of mathematics history might facilitate a deeper appreciation for doing mathematics, while shifting power relations from a position of produced knowledge to knowledge as complex. Incorporating history as an activity could encourage (re)considerations of mathematics, as explored above. How history is interrogated needs to follow a poststructural decentering of unitary subjects and monolithic stories. A critical history could be performed in which ideas are explored and critiqued. This method of complexifying history lends itself to a more just perspective of mathematics, one that positions the learner as a valid "knower" in one's own right. Questioning is a valid tool for (re)consideration of what is understood. In addition to the biographical information of mathematical history, the exploration of how mathematical ideas come to be accepted should be included. Then the process of doing mathematics becomes "important especially from a didactical point of view," claim Tzanakis and Arcavi (2000), for "this process includes using heuristics, making mistakes, having doubts and misconceptions, and even retrogressing in the development and understanding of a subject" (p. 201). This is a reiteration of what Davis and Hersh (1981) posit, that the presentation of mathematics "in textbooks is often 'backward.' The discovery process is eliminated from the description and is not documented" (p. 282). A shift in presentation exposes students to what mathematics "in the making" might mean (Tzanakis and Arcavi, 2000, p. 202).[49] Mathematics can be conceived as a human endeavor, not as facts or truths that are already determined.

Imagine a university campus. When new construction occurs, workers wait to lay down some sidewalks until the walking paths of students expose where these sidewalks should be

[49] A similar argument is made by Gerald Holton (1973) concerning science. See also Doll (2005) on this point.

placed. Now imagine the future of mathematics. It is not pre-determined. We do not know where it is going. In fact, "the path that mathematics follows—what mathematics comes to be—is a path that is laid down in walking, not one toward a pre-given end" (Davis, 1996, p. 79). Current mathematical texts are filled with clever explanations of already formed mathematical concepts. The job of the student is to "learn" these concepts, not as new (and ideally, historical) discoveries for themselves but as fixed, static, unquestioned truths. What a difference it might make if teachers were to present "mathematics—as with other disciplines—as an epistemological system, with its specific dynamics, and in its sociocultural and historical perspective, and not as a finished and static body of results and rules" (Walkerdine, 1990, p. 23). This might allow students to engage in recognitions of how lived experiences and understandings can relate to productions of knowledge—an activity in which they can play a part/role. To be simultaneously "product, producer and process" (Davis, 1996, p. 9) is to exist as a complex subject.

This (re)conceived "method" for approaching mathematics explores some reasons why, in both the methodological and epistemological sense, mathematics might be an important intellectual activity in which students should engage. Beyond arguing that mathematics is needed in "real life," when in fact fewer professionals use "school" mathematics today (Keitel, 1989, p. 8), mathematics is a method for seeking patterns. Historical texts that present mathematics as patterns in specific cultural settings should include how mathematical concepts are not static but knowledge that is argued and continually reconsidered within society. These texts can be used as resources to discuss the constant shifts in mathematics, and they are good counterexamples to the perception that knowledge is predetermined and objectively constructed. Teachers can be (re)positioned as learners who participate in hermeneutic conversations that explore mathematical ideas and concepts. Method becomes an ongoing, complex act of engagement in which the end is not predetermined and the destination unknown.

As we walk on, journeying, experiencing, and reflecting, we should remember to “take Wittgenstein’s warning to heart and avoid introducing postmodern approaches to meaning as *the* way of understanding” (Fleener, 2002, p. 140). Our way is one way, my way, your way, we are all walking, journeying, experiencing, reflecting, living out choices, interpretations, and moments we can never again know or understand in the same way in the next moment.

Embracing these interpretations, engendering instead of gendering mathematics, I invite us all to consider the work of mathematics education researchers whose work offers counter-narratives to *the* way. Their ideas stimulate possibilities for (re)conceptions of mathematics teaching in which emotion, passion, conversation, histories, discoveries, and much more are all a part. In learning to teach and teaching to learn, David Jardine, Patricia Clifford, and Sharon Friesen (2003) invite us to consider the significance in of incorporating these aspects of life:

> It is our belief that when curriculum is divorced from real life, children often lose connections with their own memories and histories. They lose touch with who they are. They may exist in our eyes more as students than as emerging selves, and we wonder if they continue to learn in any passionate sense of that word. (p. 21)

Histories and memories are important aspects to consider in the curriculum. Whose histories are considered and whose memories are valid are both questions we as educators should consider. Now I redirect the conversation to those I believe are passionate about learning and are passionate about others learning as well, specifically with respect to mathematics. Interpretations of mathematics as a field and as a curriculum area are addressed.

Mathematics in Relation

> Mathematics, originally a way of modeling our ideas about nature, soon became mistaken for an exact representation of the inner workings of nature. (Fleener, 2002, p. 42)

Gregory Bateson (2002) believed that pattern recognition is part of understanding, of interpretation. He performed an experiment involving newspaper articles. He cut out headings with the same font size and held one up for a colleague to read. Then he took a step back and held up another. He continued this until the person could not read the title that was held up. Without moving, he read the title out loud. In astonishment, the title came into vision for the colleague, and he could now “read” it. Bateson (2002) interprets this phenomenon as a pattern of perception.

I recently was in the market for a new car. I focused on comparing two specific vehicles. Amazingly, I started seeing these two vehicles everywhere, which I had not before noticed. I relate this to mathematics education in that when I am working in a particular area, such as complexity theory, everything I read seems to connect to ideas in complexity. While this is a fun game of patterns and connections, it is only one perspective. What I had not before recognized, I now interpret as seeing, as understanding in a different way.

Interpreting mathematics and education from different positions of interpretation allow us to discard “the lenses of modernism and [find] suitable replacement lenses, [and this] may make all the difference in the world—as long as we realize that even our new lenses filter our way of seeing and living. We must endlessly recreate heart” (Fleener, 2002, p. 195). It is in this recursive pattern of recreation that we continue to find different ways of conversing, experiencing and interpreting knowledge. In the last section of this chapter I offer the works of mathematics educators who are not all seeing through the same lens. The researchers offer unique interpretations, diverse perspectives, and different questions. I am not introducing their research as unified but multiplex, multi-faceted, interwoven, both same and different. By intertwining their questions and interpretations, I hope to create a complex conversation between and among their various texts.

Mathematics, as a field, a discipline, a curricular area, etc., maintains the position of a particular system of beliefs, proved by an internal logic that validates and perpetuates certain "truths." In the modernist sense, mathematics represents "how nature works," as critiqued by Walkerdine (1994) and Fleener (2002). The mathematics education researchers I present in this chapter challenge this modernist perspective, engaging in mathematics education from different perspectives. Each influence the conversation with a unique interpretation for how teachers and students can engage in mathematical conversations, explorations, and discoveries without the perpetuation of teaching as telling, most often interpreted by students as the game of figuring out what the teacher is thinking and repeating it back. I bring these researchers together under the three themes of the "basics," culture, and language-games. Through their questions relating to each of these, I intend to show how mathematics education can be about complex conversations in which we can to think the world together.

Mathematics and the "Basics"

One perspective in current mathematics literature, as outlined in Chapter 2, is the notion of basics. Relying on modernist interpretations of foundations, building blocks, hierarchies, many mathematics educators believe that in order for a student to understand one concept, that student must be fluent, proficient, in the more basic concepts that lead up to the more difficult one, such as knowing addition to perform multiplication. Fleener (2002) objects to this back-to-basics movement by claiming it is a “reaction to the challenge that society is not progressing, that our children are not smarter and better off than we were, and that society is deteriorating” (p. 22). I concur, adding that I often hear comments that our children no longer know anything because they cannot spout out multiplication facts. What amazes me is the lack of sensitivity to others’ interpretations for what is defined as knowledge or how someone else might answer differently what it means to educate. In tutoring one high school senior, I was fascinated that he could work with imaginary numbers in intuitive and insightful ways, but every time he was asked to divide 27 by 3, he had to use his calculator (and this happened on numerous occasions). One interpretation from these interactions might be that he must not know his basics, so he will never be successful in advanced mathematics. I disagree with this perspective, and I argue that his mathematical sensibilities are worthwhile and valid. His inability to divide may have nothing to do with his mathematical abilities. I believe there are other issues at hand.

Jardine, Clifford, and Friesen (2003), in their book entitled *Back to the Basics of Teaching and Learning*, reclaim the notion of basics in education:

> An interpretive understanding of “the basics” begins by imagining the disciplines teachers and students face in schools, not as objects to be broken down and then doled out in ways that can be controlled, predicted, manipulated. Rather, an interpretive understanding of the basics entails that these matters be considered more in the manner of shared and contested and living and troublesome *inheritances*. (p. 53)

These curricularists invoke an interpretation of the basics that includes histories, inheritances, care, love, and relationships, and they invite educators to imagine differently what the “basics” might be. The authors “contend that under the inherited image of ‘the basics,’ breakdown has become no longer a *response* but a *premise*: ‘Breakdown’ runs ahead of teachers and learners and turns the living field of mathematics, for example, into something broken down in such a way that, paradoxically, it is now *all* problems" (p. 6). Basics-as-breakdown is a notion prevalent in teaching, an idea which Jardine, Clifford, and Friesen vehemently oppose. Their notions of teaching and learning embrace hermeneutical engagements in conversations around ideas, emergent within the community of learners. They imagine school as different, and they share their ways of being-in-the-world:

> Schools can be treated as dealing, not with the dispensation of finished, dead, and deadly dull information that students must simply consume, but rather with troublesome, questionable, unfinished, debatable, living inheritances and with the age-old difficulty of how to enthrall the young with the task of taking up the already ongoing conversations of which their lives are already a part. (pp. xiii-xiv)

Their struggles and desires to enthrall their students and to invite them to participate in the "already ongoing conversations" lend a different approach to teaching mathematics than the ways in which the current dominant discourse seems to convey.

Jayne Fleener and Gloria Nan Dupree (2002) share their ideas for working with mathematics teacher educators. They proffer the notion of *autobiosophy* as a way to enthrall and engage their students (who are at the university level, different from Jardine, Clifford and Friesen, who are in elementary grade classrooms) to explore who they are in relation to mathematics. Autobiosophy is defined as "building on Wittgenstein's notion of autobiography as confession, denying the Cartesian privileged knower, and engaging in Michel Foucault's critical perspective of the emergence of self through language" (Fleener and Dupree, 2002, p. 75). They describe their use of autobiosophy in a mathematics education course (in which they cite Foucault (1986) at the end of their explanation):

> provided our students ways of exploring their relationship with mathematics and provided an interpretive framework for understanding how their written and verbal conversations evolved and their understandings changed. Autobiosophy, through gynocritical inquiry, became a tool for our students for (re)inventing themselves, evolving new understandings, changing meaning structures, and "setting up and developing relationships with the self, for self-reflection, self-knowledge, self-examination, for deciphering the self by oneself, for the transformation one seeks to accomplish with oneself as object" (p. 29).[50] (Fleener and Dupree, 2002, p. 75)

The authors invite their students to examine their identity as a knower of mathematics, not in the *basic*, modernist sense, but in the relational, identity politics way. This method of interrogation of the self with respect to other, echoes Fleener's (2002) sentiments as to what she believes is meaningful as an educator: of imagining "students, learning, and schooling as *relationships* and *contextual*" (p. 80). As she says:

> This change in what I believe to be most fundamental, namely that students are complexes of relationships rather than things, living within individual and social contexts, has completely affected what I feel is important in my own classroom, how I approach instruction and think about teaching, and how I view assessment. (p. 80)

This change, what she claims as fundamental, I interpret as a basic for her. If this is truly the perspective for a mathematics educator, how might instruction reflect this? I believe her use of

[50] This term is more than just autobiography, particularly Pinar's method of *currere*. For an example of *currere* that is used in the classroom, see Doerr (2004), who utilizes Pinar's *currere* in her teaching of ecology. In her interpretation of Pinar's *currere*, she perceives that Pinar and Grumet used "*currere* to examine the students' responses to their own educational experiences so the teachers-in-training could see for themselves the baggage they would bring with them into their own classrooms" (p. 14). In this way autobiography relates to Fleener and Dupree's (2002) notion of autobiosophy.

autobiosophy is one way in which she is inviting her students to share in this perspective, that everything is relational and contextual, even mathematics.

Mathematics and Culture

Peter Appelbaum (1995) argues that mathematics is relational, contextual and cultural, believing that if we focus on “mathematics as a cultural resource, we might have a very different kind of mathematics—one in which mathematics is an ongoing dynamic form of communication among people, and which is malleable in the ongoing creation of meaning” (p. 193). Mathematics is, in fact, not an absolute, a set of truths that are fixed and static, but contains “truths” while always in relation to the systems of logic in which they function.[51]

One example of cultural influences in our interpretations comes from a moment in my class when a student mentioned that she liked mathematics because it has universal truths. I commented that Umberto D’Ambrosio shared a story about male and female triangles. The entire class giggled, but they were intrigued. I replied that this is funny to them because it is different from what they (think they) know about triangles, and asked if mathematics is universal, then how can there be different names and interpretations? What might this mean for the contexts in which mathematics is learned? The defaults in our language are embedded and influenced by our educational and cultural experiences.

In a curriculum studies analysis of mathematics, Appelbaum (1995) asserts that mathematical knowledge is culturally relevant. He offers how one can interpret mathematics differently from an acultural, universal interpretation:

> I am proposing to interpret mathematical knowledge as inseparable from larger contexts of (educational) practice in which the nature of mathematical knowledge, what counts as

[51] I pursue this notion in more detail in Chapter 5. Also see Peirce (1898/1992) for a more critical analysis of mathematics as probabilities, not absolutes.

> "doing mathematics," and what is conceived of as relevant to the content and context of mathematics, are all aspects of practices that are in many respects particular to their social and cultural setting. In such settings, people actively maintain and/or transform these practices in an ongoing construction of meaning. (p. 10)

Appelbaum's (1995) ideas about ongoing construction parallels Brent Davis's (1996) metaphor of a sidewalk being constructed out of pathways. These ideas also relate to Jardine, Clifford, and Friesen's (2003) work in inviting students into the already ongoing conversation. Knowledge is perceived as continual (re)creation rather than a pre-existing entity waiting to be found. Teaching mathematics becomes a playful activity of interpretation instead of a teacher trying to pour into a student, to tell them (whether directly or indirectly) what the teacher already knows to be true, as Jayne Fleener, Andrew Carter and Stacey Reeder (2004) have found: "Educators have failed to teach mathematics as sharing a form of life. Those who learn to play the game of mathematics reveal a form of life through their actions, including the language games, in which they participate" (p. 467). Language games are another lense with which mathematics education can be seen.

This brings us back to the work of Jardine, Clifford, and Friesen (2003), three willing participants who long to share meaningful conversations with students, to play-with rather than play-at or play-in (described below). Their continual engagement in the languages that students offer is deliberate, intentional, and they constantly engage in the interpretive task, which they define as inquiring "what is hidden in language, what is deferred by signs, what is pointed to, what is repressed, implicit, or mediated. What thus seem initially to be individualistic autobiographical searchings turn out to be revelations of traditions, re-collections of disseminated identities" (p. 58). Their basics of teaching involve this mode of inquiry, investigations of language, "sedimented layers of emotionally resonant metaphors, knowledge, and associations, which when paid attention to can be experienced as discoveries and revelations" (p. 58). Language allows for interpretations of mathematics and culture, and together the two influence teaching and learning.

Mathematics and Language-Games

In addition to a set of building blocks and a system of fixed truths absent of sociocultural influences, mathematics in a modernist frame is also perceived as a language to be learned. Fleener, Carter and Reeder (2004) examine interactions in a mathematics classroom from the Wittgensteinian interpretive frame of playing-at, playing-in, and playing-with language games. The first notion of play focuses on precise language construction and use of terminology. The second, playing-in, implies particular roles for students and teachers to play. The third category, playing-with, invites shared, contextual understandings in which all are playing around with ideas in which "new meanings may emerge as the game continues and language takes on an 'as if' quality. In the mathematics classroom, 'playing-with' language games tend to be generative as contexts are invented to extend meanings" (p. 449). Fleener, Carter and Reeder (2004) propose that mathematics teachers do not allow for playing-with mathematics.

Considering how mathematics is cultural, contextual, and a language game, could affect the current epidemic of math-phobia found in the United States today. "For many students," Fleener, Carter and Reeder (2004) contend, "the language games of mathematics are deficient, revealing mathematical meanings as disjoint and disconnected to everyday experiences" (p. 447). Observations of what language-games are occurring in classrooms

> allow us to reinterpret instructional practices by enhancing our understanding of the social dynamics of the teaching–learning process. In particular, this approach suggests

> moving beyond treating mathematics as a "subject" to be learned or information/skills/knowledge to be disseminated or transmitted to our students. Instead, the language-games approach may offer a richer understanding of the teaching–learning relationship as a social meaning structure that dialectically pervades both individual and social spaces through the language games being played. (p. 452)

Mathematics exists in social spaces, in the momentary creations of those language-games in which students and teachers play. A (re)interpretation of mathematics as a language-game allows teachers to recognize that they are a part of a conversation, not the facilitator, linguistic trainer, conductor, or director, but a participant in this shared space.

Fleener, Carter and Reeder (2004) connect their interpretations of language-games with Davis's (1996) categories of listening: evaluative, interpretive, and hermeneutic. These three ways of orchestrating classroom conversations indicate a positionality of the listener and implicate a type of conversation in the classroom. Evaluative listening implies that the listener is looking for particular key words that fill in the blank. Interpretive listening is more interactive, inviting the speaker to elaborate on particular ideas, but there is still an intentionality underlying the discussion[52] in which the teacher/listener is attempting to assist the student/speaker in reaching a particular pre-determined conclusion. In contrast, hermeneutic listening involves all in a conversation in which no one knows the destination, if there even is one.

Underlying all of Davis's works throughout the last decade are his penchants toward the works of Maurice Merleu-Ponty, Hans-Georg Gadamer and Francisco Varela. These three seem

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[52] Davis (1996) distinguishes a discussion from a conversation in that a discussion is when speakers are engaged in speaking from particular perspectives with a desire to convince someone else of their opinion without a willingness to listen, engage or negotiate with anyone else. A conversation, in contrast, is a mutual negotiation in which all are transformed as a result of the interaction. This relates back to the beginning of the chapter, in which the speaker asks, "Please understand." This is an example of a discussion, not a conversation. For more on conversation, see Chapter 5.

to be extremely influential in his considerations of phenomenology, hermeneutics and complexity sciences, respectively. Together they inform and shape Davis's logic of relations. Epistemological and pedagogical considerations based in part on each of these leanings reveal quite a different approach to education than the current discourse seems to present. In my next chapter, I explore, explain, and expand upon my pedagogical strategies and epistemological perspectives. Included in this is my justification for using Davis's (1996) *Teaching Mathematics: Toward a Sound Alternative* in my undergraduate course. His explorations of phenomenology, hermeneutics and complexity science invite students into conversations about more than just *how* to teach mathematics, and I analyze classroom conversations and students' responses to these approaches. In addition, I show how my work as a researcher and educator compares and contrasts with those whom I have termed as "alternative."

Chapter 4: One Teacher Educator's Story

> Pre-service teachers need to experience the research process in ways that allow them to articulate and reflect on their personal versions of teaching rather than merely imitating the articulations of others. (McWilliam, 1994, p. 149)

In previous chapters, I have outlined interpretations of mathematics, teacher education in traditional forms, and alternative approaches to mathematics teacher education. Now I present my current epistemological considerations and pedagogical strategies, showing similarities and differences, hoping to move away from teaching-as-telling toward ideas of "thinking the world together" (Jardine, Clifford, and Friesen, 2003). I connect and draw on the works of those mentioned in Chapter 3; in addition, I integrate the works of David Kirshner (2002) and William Doll (1993, 2002, 2005) in ways that I do not find in the current literature for mathematics teacher education. Furthermore, I find that my work resonates with perspectives in feminist teacher education research (Britzman, 1997, 2003; Gore, 1993; Lather, 1991; McWilliam, 1994; Miller, 2005) and hermeneutical inquiry research (Brown, 1997; Herda, 1999; Ricoeur, 1991), and I relate these modes of inquiry to my work in elementary education pre-service teacher education courses. I will draw out connections with these forms of research as I describe my pedagogical approaches.

These stories are not without complications, of course, and the "trouble is doubled for the difficulty is in understanding one's own voice even as one strains to hear the voice of the other" (Britzman, 1997, p. 31). My goal is not to elevate my ideas as "what works" but to provide narratives that allow for conversations about differences.[53] I hope to engage in complex conversations that recognize certain problematics in the act of "doing" research, namely that the "rules of discourse and engagement cannot guarantee what they promise to deliver: the desire to know and be known without mediation and the desire to make insight from ignorance and identity" (p. 32). Though the desire to provide insight may be noble, the objectification of both self and other becomes a concern, a static, fixed caricature instead of possibilities of dynamic, complex, interrelated and co-implicated moments of being. These stories help set the stage for Chapter 5, in which I analyze complex conversations and possible curricular implications.

Parallel to the narratives in this chapter, I outline the work of William Doll (1993) and his development of the four R's as a (re)consideration for teaching complexly. Struggles and tensions that occur in my teaching relate to these ideas, and I share them as my moments of teaching complexly. I follow by presenting David Kirshner's (2002) crossdisciplinary strategy and share how this strategy can proffer particular beginnings for students to share their experiences and influences in mathematics education. The assignment of writing a mathematical autobiography is included to demonstrate that (re)imagining our histories in educational experiences can do more than just acknowledge who we are. This form of writing can spur us to move "beyond the 'clear images' in which debate has been conducted on the familiar terrain of teacher education policy as folklore," as McWilliam (1994) so passionately conveys, and instead consider what it means to pursue

> better educational practice for ourselves and our students, [for] we must acknowledge and confront the partiality of our own stories and their potential for surveillance and

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[53] I intentionally use the phrase, "what works," to play against the current discourse in education and politics, specifically the creation of the government-sanctioned *What Works Clearinghouse: A trusted source of scientific evidence of what works in education* (What Works Clearinghouse, 2005).

> repression. And to do this, we must keep generating new strategies for storytelling, not continue to rely on old plots. (p. 22)

The work that occurs when we are engaged in teaching complexly and autobiographically lends itself to considerations for transformations. The act of transformation, however, carries with it ethical implications. I pose some questions and considerations for what it might mean for pedagogy to allow for transformative moments in ways that are gentle and engage in the changes that we all undergo as a result of our shared moments and experiences. In the words of one of my students:

> *The experiences and knowledge that the students bring to a classroom have a significant effect on the way they learn new information. We taint everything that we learn with our own beliefs, conceptions, and perspectives that we held previously. By learning something, we make it ours, thus leaving our prints on it just as it leaves an impression on us*. (David, Fall, 2002)

Struggles and Tensions

In my work with pre-service teachers, I strive to move away from the teaching-as-telling mode and toward an open, dynamic, and interactive approach. My ideas are not new, nor are my pedagogical strategies. They are only personal interpretations that have emerged and continue to emerge from my research and my experiences. I work to teach complexly, continuously envisioning moments in which we can engage in ways of being that resonate with Doll's (1993) four R's—recursion, richness, relations, and rigor—which he offers as new criteria for curriculum. Each curricular concept is connected with the others, and together they form an alternative to the schismogenic[54] path that education is currently taking. Doll (1993) posits a new context for a richly related curriculum that rigorously challenges students as they recursively reflect on their connectedness and express their creativity.

First, richness "refers to a curriculum's depth, to its layers of meaning, to its multiple possibilities or interpretations" (Doll, 1993, p. 176). Curriculum strands, content standards, these all have richness within them. The method with which this richness is engaged is the difference that makes the difference (Bateson, 1979/2002, p. 27). Instead of focusing on how to impart factual knowledge transference, educators should employ hermeneutic methods. "Another way to state this," Doll (1993) suggests, "is to say that the *problematics*, *perturbations*, *possibilities* inherent in a curriculum are what give the curriculum… its richness" (p. 176). Students can "play around" with ideas, concepts, and information, and interrogate underlying assumptions associated with knowledge. No matter the subject matter, "dialogue, interpretations, hypothesis generation and proving, and pattern playing" (p. 177) can be used as pedagogical practices that transcend simple transference of information and move toward a rich curriculum.

Second, recursion is a transformative process that relates to the mathematical operation of iteration. "In such iterations," claims Doll (1993), "there is both stability and change; the formula stays the same, the variables change (in an orderly but often nonpredictable manner)" (p. 177). This notion of transformative looping is different from repetition. Repetition "is designed to improve set performance. Its frame is closed. Recursion aims at developing competence—the ability to organize, combine, inquire, use something heuristically. Its frame is open" (p. 178). Recursion is significant because it allows for continual reflection that stimulates and generates new information. Doll (1993) relates this process to Dewey's secondary experience, Piaget's

[54] Schismogenesis is a theory of relations in which the interactions between those involved continually reciprocate certain roles performed that cycle towards destruction. This term was created and developed by Gregory Bateson (1958) in his anthropological work with the Iatmul and their transvestite ritual called *Naven*.

reflexive intelligence, and to Bruner's statement that it is necessary "to step back from one's doings, to 'distance oneself in some way' from one's own thoughts" (p. 177). In the classroom dialogue becomes an important tool for recursive experiences. Doll (1993) emphasizes this point: "Without reflection—engendered by dialogue—recursion becomes shallow not transformative; it is not reflective recursion, it is only repetition" (p. 177). A transformative curriculum allows transcendence, creativity, and reflexivity to occur within recursive dialogues. These dialogues are simultaneously generating new experiences and knowledge on which participants can continue to reflect. This process is an open, unpredictable, generative method for learning.

The third "R" is relations, and the concept of relations directly connects with both richness and recursion. Doll (1993) categorizes relations as pedagogical and cultural. Pedagogical relations are considered "conditions, situations, relations [that] are always changing; the present does not recreate the past (though it is certainly influenced by the past) nor does the present determine the future (though it is an influencer)" (p. 179). Recognizing rich and recursive relations among conversants, as well as within oneself, is a task for all involved in the conversation. The teacher is a facilitator that recognizes and initiates learning opportunities in which relationships are nurtured. Doll (1993) contrasts these types of relations with cultural relations that occur within discourse, narration and dialogue. These relations are important in the curriculum because "discourse now becomes what Jim Cheney (1989) calls 'contextualist' (p. 123)—bound always by the localness of ourselves, our histories, our language, our place, but also expanding into an ever-broadening global and ecological network" (p. 180). We are all contextually bound—not bound in the modernist restrictive sense, rather our situatedness that is ever-changing, ever-shifting, dynamic. Thus, we must consider how "on the one hand, to honor the localness of our perceptions and, on the other hand, to realize that our local perspectives integrate into a larger cultural, ecological, cosmic matrix" (p. 181). Allowing these considerations to affect how curriculum is shaped and developed creates moments for learning to become a rich and recursively related experience.

The fourth "R" that Doll (1993) presents is the notion of rigor: "purposely looking for different alternatives, relations, connections" (p. 182). Rigor implies curricular opportunities for students to critically analyze concepts and deconstruct the assumptions and frames within which these concepts are defined. Functioning within this rigorous frame, allowing for a dialogue that is meaningful and transformative, and "combining the complexity of indeterminacy with the hermeneutics of interpretation, it seems necessary to establish a community, one critical yet supportive" (p. 183).[55] Postmodern ideas do not discount the importance of learning information; in addition to learning, critical thinking becomes an essential component. Deconstructing underpinnings of knowledge and the assumptions that accompany information allows for interpretive frames to expose the limitations of such knowledge as well as to stimulate new perspectives and approaches to learning. "Facts" no longer remain absolutes but are (re)considered in the context within which they were generated. This allows for a content-rich curriculum that considers the relationships of knowledge. Knowledge is not eliminated, and learning still occurs. However, students are able to recursively reflect on the connections with which this knowledge came to be determined, and put forth how these patterns could be (re)considered.

Struggles

A theme that emerges through my work in my classroom with the four R's is the notion of struggle. Allowing students to struggle with mathematics in a "safe" environment can nurture

[55] To be both critical and supportive is a post-modern notion of refusing dichotomies. We should not eliminate what already exists that is positive, but we should analyze and consider possibilities and limitations, which I explore in the context of complex conversations in Chapter 5.

different ways of being mathematical. This concept comes forward in two ways. The first way is in our work with the problems of the week. I encourage students to answer the problems in their own way, and I do not ask for correct answers, only attempts, playing-with the questions (see Fleener, Carter, and Reeder, 2004; Chapter 3, this volume). I ask them to work things out on paper. Why do they insist on performing calculations in their head? What is wrong with writing out operations? I often see them "sneak" a calculation on a scratch sheet, or they erase any work they feel is too "elementary" to warrant writing it. Why is this? What is occurring in school that elicits this sort of behavior? I encourage them to embrace that mathematics is messy! One example I give to relate is in the context of the movie, *A Beautiful Mind*, in which John Nash (played by Russell Crowe) plays around with mathematical ideas on windows, notebooks, chalkboards, everywhere, and that it is not neat. The only mathematical ideas that the "layperson" sees is the nicely argued mathematical statements in textbooks.[56] Rarely do we (non-mathematicians) see playing around with mathematical ideas or performing calculations. The sense of struggle so well-performed by Nash (Crowe) is just one example in which students can embrace that mathematics does not have to be perfect, well-executed, precise steps. Mathematics can be about ideas, patterns, connections, and these can emerge when students are allowed to struggle.

A second way in which we (by this, I mean me and my students) struggle is playing around with a particular mathematical concept over an extended amount of time. For example, in the fall of 2004 I was tutoring a sixth grade student, and I realized that she learned concepts better when I offered her visual tools. We were working with dividing fractions, and I was stumped; I could not create a visual explanation. I researched and found a chapter by Liping Ma

[56] As mentioned in Chapter 3, textbooks show mathematics in completed, logical steps and "the discovery process is eliminated" (Davis and Hersh, 1981, p. 282).

(1999) in which she explores ways of representing division by fractions and compares the responses of American and Chinese elementary teachers. I asked my class the following day if they could explain conceptually how to divide two fractions. I placed an example on the board, and I even told them the answer! We worked for two weeks on this problem, all of us. I brought out manipulatives, we drew diagrams, some even brought notes from previous classes. We all read Ma's (1999) chapter and discussed the problem some more. We never reached a conclusion, but we had many conversations. This challenge did not go away, and many students revisited this problem again and again. Allowing time to struggle became an important quality, for many students at some point in our following classes would mention as an aside, "I think I figured it out," and show me their understandings of division and fractions.

I thoroughly enjoyed this activity because many of my students became comfortable with struggling with mathematical concepts. I attribute part of the success (of their shift in comfort level) to the fact that I was struggling as well. I believe that Jardine, Clifford, and Frisen (2003) have it right, that "if we are prepared to take this risk ourselves, that second grader's questions can be treated generously, as really good mathematical questions that open up a pedagogical territory worthy of teachers' and students' attention and devotion" (p. 8). I repeated the same idea of struggling with a concept the following semester as well.[57] At the end of the course, I asked students to read the list of course goals as outlined on the syllabus, choose one, and explain how that goal has been achieved for them personally. In particular, one student responded to the idea of struggle. Alicia chose the goal: "to improve personal understandings and attitudes towards mathematics" and wrote:

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[57] I admit the experience of struggling with this problem did not seem as generative as the previous semester. I attribute this to the fact that the struggle was not an emergent one. In the fall 2004 class, as the "instructor" I was struggling as well. In the spring 2005 class, I felt I "knew" how to visually and tacitly explain dividing fractions, and I think my students could sense that. I tried to maintain my playfulness, but I was not really taking any risks. I struggle with the decision I made and wonder if it was more repetitive than recursive.

> *At the beginning of the semester, I thought I would not really want to teach math. It would not have been my first choice; however, this semester has changed my mind. This class has made me appreciate math and view it in a different way. First, I have learned more about teaching math. I guess I kept thinking I would teach math the way I was taught, but this class has made me realize there are many different approaches to teaching math. I have learned it is ok to allow students to explore and discover ideas. Also, I think it is good for students to struggle with ideas. I learned this with dividing fractions! This struggle made me appreciate this concept more. Now, I feel I have a positive attitude about math.* (Spring, 2005)

Her struggle with dividing fractions did not go unnoticed. I wonder if she had not had this kind of opportunity in previous mathematics classes. I am fascinated by the connection between being allowed to struggle and acquiring a positive attitude toward mathematics. Also, Alicia was able to make a connection between her experience as a student to her role as a teacher. This is exciting to read, for I believe it is an arduous task for students to make that transition.

Tensions

At the time in their academic career in which students enroll in my mathematics "methods" class, students are identified as "pre-service" teachers, and the following semester they will be student teaching. This time of transition is difficult because I continue to ask them to interchange roles of student and (future) teacher. One problem that arises every semester is their complaint that the activities I do with them are not ones they will use in their elementary classrooms. For example, I had a few complaints after an activity involving the manipulatives called *AlgeBlocks* (Johnston, 1994). I begin the activity by asking them to simplify the expression: $(x + 2)(x + 3)$. Some remember the "trick" immediately, while others hesitate. I "remind" them to FOIL (First, Outside, Inside, Last), and then they are all able to arrive at the answer. Then I ask, "Why? Why is this the answer? What does this mean?" The response: "It just is."

I distribute the *AlgeBlocks*, and in pairs and as a class we work through ideas about area, multiplication, distribution, like terms, and other mathematical ideas that relate to multiplying binomials. The use of manipulatives creates an opportunity for visual representations of mathematical ideas to connect with what students already know about these ideas and to possibly understand them in different ways. By the end of the class, my students respond with comments that give the impression they are excited about understanding FOIL instead of just knowing the answer. When they write in their journals and reflect on this activity, these comments are repeated; however, some students complain that they will never use the activity in their elementary classroom[58] and question its pertinence to their future.[59] Here is the response I wrote to the class overall, on February 3, 2005:

> *After reading your journals, I want to pass on a note for you to think about. I used the AlgeBlocks in our class because I realize that while most of you could get an answer to multiplying two binomials, you might not understand conceptually why FOIL works. This activity was used to help you consider: Why do students know steps to solve mathematics problems yet do not conceptually understand the mathematics behind it? Because you have had many opportunities to conceptualize the more simple constructs of*

[58] After the students participated in their field experience, one pair shared a "new" way of multiplying they learned from their cooperating teacher, called "Egyptian" math. They showed our class the process: 63*71 = (60+3) (70+1) = (60*70) + (60*1) + (3*70) + (3*1). I then showed how their demonstration related to multiplying two binomials (FOIL). The reaction from the pair was interesting. One became very excited and animated about the connection; the other became subdued and pensive. Only days later did the second one come to me privately and share her thoughts about the connections she made.

[59] Vianne McLean (1999) proposes this happens due to the fact that "on the basis of their knowledge, beginning teachers typically conceptualize the process of learning to teach as a cumulative acquisition of concrete technical and organizational skills" (p. 59), and these beginning teachers just want to know, "What works?" (p. 71).

operations with whole numbers, I wanted to challenge how at some point you learned steps but not why *the steps work.*

As we do things in our class, I consider you to be students, not teachers. At the same time I am asking you to consider how this might translate for you when you become a teacher. This is a tension you will have to negotiate all semester. I know it is going to be difficult, but I think you are up to the task.

So when you read about hermeneutics or do activities like AlgeBlocks, I would like to encourage you to not focus on using these specific ideas in the elementary classroom. Instead, ask yourself, how is this affecting me as an elementary education major? I am not going to do activities for you to imitate; rather, I want to encourage you to know yourself better as a prospective teacher. I am trying to provide stimuli for you to grow, both in your knowledge of mathematics and of teaching philosophies.

I look forward to many more great class conversations like the one we had on Wednesday.

This tension of negotiation between current student and future teacher remains problematic. I think pre-service teachers are capable of navigating this tension, but barriers exist as a result of prior experiences and current assumptions about teacher education courses (especially "methods" classes). Thus, I reiterate throughout the semester that the tension will continue to exist and needs to be considered.

Epistemologies and Autobiographies

Another aspect of my work in this teacher education course involves encouraging pre-service teachers to articulate their own teaching philosophy. In addition to the struggles with respect to mathematics, they also struggle in their ability to express what they believe about students "coming to know." With this in mind, the first week of class I require my students to read David Kirshner's (2002) crossdisciplinary strategy (mentioned in Chapter 2). I use this article as a way to help pre-service teachers begin expressing their experiences in mathematics education, vis-à-vis these three epistemological considerations (habituation, construction and enculturation). Many elementary education students today learn much about constructivism but very few have experienced learning in a constructivist classroom. Furthermore, my students seem to have very little knowledge of other learning theories besides constructivism. By reading about Kirshner's (2002) framework, students are able to articulate interpretations of their teachers' epistemologies and how that affected their own personal learning.

My students recognize patterns of habituation, constructivism, and sometimes enculturation, in their histories of learning mathematics. I start with Kirshner's (2002) article because he provides a reference from which students can articulate their agreement with or argument against incorporating constructivism into their own philosophy of teaching. The task of identifying ways in which particular pedagogical strategies accomplish different forms of learning outcomes generates interesting discussions about to which aims these students believe they want to aspire when they become the teacher. This leads to opportunities for conversations about skills, conceptual understandings, and social dispositions, and how these are significantly different pedagogical aims.

Opportunities to reason, argue and critique epistemologies are often overlooked in education courses. I believe these types of moments should occur in order for students to find ways to move away from teaching-as-telling and toward a more conversational, hermeneutical approach to mathematics education. Constructivism has particular limitations, including fixed ends to which teachers would like to "lead" students.[60] While this approach is not forceful but much more pragmatic about the path students may take to arrive, it is still the intent of the teacher for students to "arrive" at a certain location. This is in contrast to hermeneutical endeavors in which the end is not known. For these reasons, following the reading of Kirshner (2002), we read Brent Davis's (1996) *Teaching Mathematics: Toward a Sound Alternative*, all the while revisiting Kirshner's (2002) three epistemological categories. This recursive process is intended to acknowledge Kirshner's (2002) three metaphors as categories of what has already been developed in psychology, but move toward naming individually what *each* believes to be one's own philosophy. By shifting the conversation from the three metaphors toward Davis' (1996) interpretations, my students are allowed opportunities to make connections, as well as compare and contrast their experiences to ideas such as hermeneutical listening, enactivism, and non-linear perspectives. This quest for naming one's own philosophy is one way in which I encourage my students to not fall into the trap of "gracious submission" (Pinar, 2004, p. 71), instead to bring them into the already ongoing conversation about what it means to teach and learn.

Autobiographical Work

As we work through considerations about connections between their experiences and current learning theories, I ask my students to write a mathematical autobiography. This activity is similar to the work of Joy Ritchie and David Wilson (2000), who work in the context of reading, literacy and teacher education, and resonates with their belief that "how these students were taught—and what they were taught—has influenced their beliefs about English instruction" (p. 42). I believe this is also true in mathematics education, and I create an opportunity for my

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[60] For a thorough analysis of some limitations of constructivism, see Davis and Sumara (2002).

pre-service teachers to articulate these beliefs and influences. My specific assignment is as follows:

> *Autobiographically present your experience in mathematics education (classrooms throughout elementary and secondary schooling). Incorporate your interpretation of what rationale–using Kirshner's (2002) metaphors of habituation, construction, or enculturation–you think your teachers used, and how that affected your learning of mathematics.*

This task is a complex assignment. For instance, students have rarely considered their teachers' epistemologies, pedagogical strategies, and their relationships to teachers and mathematics as a result. "Issues of pedagogy," argues Britzman (2003), "do not enter into a student's view of the teacher's work:"

> Rather, the teacher's skills are reduced to custodial moments: the ability to enforce school rules, impart textbook knowledge, grade student papers, and manage classroom discipline appear to be the sum total of the teacher's work. Hidden is the pedagogy teachers enact: the ways teachers render content and experience as pedagogical, consciously construct and innovate teaching methods, solicit and negotiate student concerns, and attempt to balance the exigencies of curriculum with both the students' and their own visions of what it means to know. (p. 27)

I encourage my students to write about their own mathematical experiences, how these experiences have shaped their perspectives of teaching mathematics, and who they believe they are in relation to mathematics, hoping to bring what was previously hidden to the foreground.

Often to their surprise, they realize particular issues they have with respect to mathematics. Furthermore, they desire to pursue new identities, ones that take into account who they are now, and who they desire to become. What was there does not have to remain. Rather than viewing autobiography as a fixed perspective of the past, this form of discourse is a "reflective process that allows the mind to wander but notes the path and all its markers" (Grumet, 1980, p. 25). In this activity, the student acts as an arranger who continually attempts to make connections but also reveals "those cracks in the smooth surface of our conceptual world that may suggest new interpretations of human experience" (p. 29). This opens spaces to spur a "process of creating an interpretative community in which lived experience can be discovered, expressed, and interpreted is one, in Miller's phrase, of 'creating spaces'" (Pinar et. al., 1995, p. 524). The act of writing is not an inherently libratory process, nor does it ensure learning.[61] Instead, the request for students to write allows for possibilities of raising questions, not providing answers. I do not expect my students to have a revelatory experience or epistemic moment in this assignment, although the potential is there. By writing an autobiography of mathematical experiences, students begin to recognize who they are becoming in relation to mathematics.

In these stories, writing and sharing, the students have a reference point with which we can converse and reference in the remainder of the course. In a similar way, Ritchie and Wilson (2000) share how they empower their own students and give them a voice, through the use of students' writings:

> These stories become a kind of primary text in these classes, enabling preservice and practicing teachers to uncover their unspoken assumptions; examine the contradictions between their pedagogies and their experiences; complicate their understandings of literacy, learning and teaching; integrate their examined experiences into their working

[61] For an excellent analysis of the use of writing in the classroom and its limitations, see David Jardine and Pam Rinehart's (2003) "Relentless Writing and the Death of Memory in Elementary Education," which can also be found in Preamble 4 of Jardine, Clifford, and Friesen (2003).

> conceptions of literacy and learning; grow in understanding who they are and how they have become who they are; develop intimacy; and build community. They also provide teachers with a sense of their own authority to resist and revise the powerful scripting narratives of the culture and schools so they can begin to compose new narratives of personal and professional identity and practice. (pp. 174-175)

Autobiographical writing and personal philosophies provide these pre-service teachers with texts that empower them to resist, to refuse to submit to another's perspective just because someone else says it. Instead, students are able to compose their own opinions, based in part on who they have been, who they want to become, and in response to their readings in our course, conversations with others, and experiences in the classroom. The opportunities afforded them in the course of this semester contrasts with what Ritchie and Wilson (2000) believe currently exists for these teacher education students:

> Many of our students' formal educations had been devoid of successful, mutual, collaborative, "conversational" learning. In addition, these students had been given few—generally no—opportunities to reflect on and question their educations or the status quo of their lives. Without ongoing critical dialogues between their old and new assumptions about teaching, learning, and literacy, their new assumptions could not become fully transformative. (p. 53)

Mathematical autobiographies are merely one vehicle in which students can reflect and question their experiences in mathematics classrooms. Assumptions should be critiqued, dialogue should be open. Pre-service teachers need opportunities for self-reflection if they are going to become becoming reflective practitioners, effective professionals, and inquiring pedagogues.

Discovering Identities

The actual act of writing an autobiography is not the only way in which students can (re)consider issues of identity and their own sense of becoming. Experiences in our classroom throughout the semester can foster these moments. Each semester I begin my first day of class in the exact same way. I begin by placing the number “1/3” on the chalkboard. I ask the students to take one minute to write down whatever thoughts result from what is written on the board. (I do not even say “one-third.”) At the end of the minute, I ask students to share their thoughts. The class discussions range from the idea that 1/3 means one of three equal parts, to comparing 1/3 to 1/2, to converting fractions to decimals and percents. As students use terms such as numerator, least common denominator, and reciprocal, I write them on the board. After the class shares for about thirty minutes, I suggest that an assignment could emerge from the conversation that occurred, whether it would be to define all the terms on the board or to provide a new question that relates to what was discussed so as to begin the next lesson with what was concluded that day.[62] The conversation that ensues is not dictated by me, but as the instructor I have a role. I have two specific objectives. One is that our conversation would address several concepts associated with the NCTM (2000) *Standards*—which they always do—and the other is that students would become more comfortable in speaking in mathematical language—which appears to be true.

What I did not anticipate in the spring of 2005 was that a student would write her final exam, in her summary of our course, and reference this experience in relation to her own becoming. I provide her full text below because I feel the context of her statements is significant:

[62] This pedagogical example as well as connections to ideas in chaos and complexity theories can be found in Smitherman (2005).

Before I plunged into this semester, I felt that this course was going to be a nightmare. I am not fond of math and I really dislike it. But once I dove into your course, I discovered something more than math. I discovered myself. I never thought that this course would contain so much philosophy and personal reflection. I really thought I was going to come into this classroom and learn how to write lesson plans for math and how I could use different manipulatives within my classroom. I never in my wildest dreams thought I would take so much with me at the end.

I will be honest, there were times that I wanted to scream, but those times were few. I felt that you pushed us to find out who we were. When I walked into class one day and you put ¾ on the board (some fraction)[63] *and you asked us all to name the first thing that came to mind when you saw this, I was shocked. At first, I thought we were going to learn about fractions, but in all reality I came to understand hermeneutics through this example. You asked us "why" and pushed "us" to think "how." This started a battle inside me to find the answers to those questions. Through the many long discussions we had, I was able to discuss how I felt and then made it a reality within myself. I learned a lot about not just "doing," but thinking of "why" and "how" I am going to "do" it.*

Within my class, I will take this knowledge of who I am and hopefully try to push students to do the same. I want my class to be well thought out not just in activities, but in the "hows" and "whys." I want to make math meaningful and full of discussion, not just working out problems. I will take what I have learned in this class about myself and use it in the classroom, but beyond that it will stay in my heart forever because it is truly who I am. It is my identity. (Linda, Spring, 2005)

[63] In this text, she references a different fraction. I believe it does not matter which fraction I wrote on the board. The connections she makes among our classroom activity, course readings, and her own struggles to consider who she is becoming as a teacher are far more significant than whether she remembered 1/3 or ¾ as an example.

Linda shares her struggles, elucidations and discoveries in an emotional and heartfelt manner. These ideas did not come easy to her. She often expressed her concerns in our class conversations, and I truly believe she has emerged as a more reflective teacher-to-be as a result of her readings and experiences in this course.

The use of autobiography is not a "new" idea in teacher education. Many researchers have been using this approach for years (e.g., Pinar and Grumet, 1976; Miller, 1998; Hesford, 1999). Vianne McLean (1999) presents ways in which teacher educators are changing in their research, including the use of autobiography and stories. She describes how autobiographical "story telling" can create an atmosphere of collaboration within which beginning teachers and teacher educators come together. While I applaud her description and agree with her statement that the teller "begins to see new interpretations, new possibilities for self" (p. 80), I wonder to what extent these autobiographies and stories allow for a move towards difference. Collaboration and sharing seem to evoke a feeling of mutual agreement, a rallying of sorts. What if, in these stories, one feels outside, different, abnormal? To what degree would that be applauded, within the realm of teacher education as it is today? And how might a teacher educator nurture that type of environment? Does McLean's (1999) depiction of autobiography embrace autobiography as a "queering curriculum practice" (Miller, 1998, 2005)?

Autobiography can function as a way to shift from moving toward an identity of similarity to identity always shifting and becoming. Wendy Hesford (1999), an English professor and teacher educator, incorporates autobiography in her courses as well. Hesford (1999) believes that the "autobiographical act is no longer constructed as an act of retrieval of an already existing and complete self (the traditional view) but, rather, a linguistic act through which the self is created in the process of the telling" (p. 19). In conjunction with this process, Hesford (1999) asks, “Who am I when I am looking? Who am I *not* when I am looking” (pp. x-xi). I believe these are important questions, for autobiography involves making choices and decisions, suspending some thoughts and memories in order to present others. This perspective highlights that the stories are always partial, with more cracks, gaps and connections that can be recognized, shared.

Students’ writings both excite and scare me. My work with pre-service teachers has ethical implications. As such, it is imperative I investigate and consider how my notions of transformation and understanding do not impose violence upon my students in ways that are harmful. There is a tension I must consider: While “making appropriate judgments is the critical key to learning,” Herda (1999) claims, “we need to recognize that the judgments we make have moral implications” (p. 133). I investigate how I am implicated.

Co-Implicated in the Struggle

In Chapter 1, I asked the following questions: What ends do I, or any teacher have? Am I imposing my ends? Should I so impose? Whose politics are involved? If a teacher is working to change or transform students, the question “Why?” needs to be asked. What is insufficient in students’ current perspectives that such a change is warranted, needed? The notion of transformative education carries with it many ethical issues about transformative teaching.

Ideas like “improve,” “transform,” and “change,” carry with them certain impositions for power relations that can produce attitudes of dominance and determination that contradict the very thing I am trying to accomplish, namely that pre-service teachers become part of the already ongoing conversation about what it means to learn and to teach and that they have something unique to contribute. McWilliam (1994) problematizes her position as a teacher educator:

> The examination I undertake of the issue of improving teacher education practice is motivated by my own "struggle for pedagogies" (Gore, 1993), not my clarity about the truth of one or other of these competing discourses in teacher education. As a teacher educator, I am aware of the temptation to provide clarity for pre-service teachers by presenting my one political story rather than allowing them to do their own multiple reading of teaching stories in multiple ways. (p. 3)

In the move to allow for multiple ways of knowing instead of pushing to clarify the truth, McWilliam (1994) is able to situate herself in relation to others, becoming shared and implicated in the work that together is accomplished.

I believe the work with pre-service teachers is challenging yet exciting because there are so many opportunities to encourage their recognition for their own situatedness. It is also dangerous work because of limitations of time. "It is not enough to send teachers out with raised critical consciousness," argues McWilliam (1994),

> without addressing the "political" issues of content and technique. Simon's (1988) call for teachers to "guard against hopelessness" (p. 4) seems to be all the more urgent for pre-service teachers, who are armed with little more than awareness of social injustice and good intentions. (p. 105)

So when I ask my students, "Why educate?" as a way to listen to their ideologies about teaching and learning, am I hoping to hear what I believe, or do I "allow" them the right to their own opinion? In lieu of allowing or denying, the conversations around the answer of what it means to educate could focus on connections among political ideologies, gender dynamics, identity issues, and epistemological considerations for what these responses might imply in the context of the classroom.

As a teacher educator who draws on feminist theory to inform my pedagogical practices, I do find resistances to my approaches. I believe McWilliam (1994) articulates her experience with this well:

> The issue is how to overcome my own resistance to the assumption that "their problem" has to do with not accepting my version of reality (Lather, 1989, p. 24). This means acknowledging pre-service teacher talk as a legitimate response to the relations of power/knowledge available to them as subjects of academic, professional, and policy discourses. (p. 148)

What are my assumptions? Do I validate my students' responses in my work? As I posed in Chapter 1, how might I acknowledge difference as ways to (re)consider my pedagogical strategies? Just because I have five years of teaching experience in a middle school classroom, my ideas and opinions are no more valid than those of pre-service teachers. Tyranny of experience is not a libratory practice.

In the stories I have shared with respect to struggles, tensions, autobiographical writings, and identity politics, I believe there are potentialities and possibilities. Change can be painful, change can be liberating. If all involved in the moment are willing participants, the experience becomes transformative for all. Maybe that is where the ethical issues lie: Is the person who claims the role of "teacher" willing to be changed in the act of teaching? I agree with Ritchie and Wilson (2000), who believe "change is made possible and becomes sustainable when teachers gain critical perspective on how their identities have been constructed by/in the culture and how cultural narratives of teaching have shaped their personal and professional subjectivities" (p. 180), and I think this applies directly to teacher educators/professors. In a hermeneutical way, "it is not so much a matter of *doing* hermeneutic participatory research as it is a way of *being* a researcher…. It means learning about language, listening and understanding" (Herda, 1999, p. 93). It means playing-with, listening without intended outcomes, and perceiving connections among and between. Pre-service teachers cannot be perceived as objects, or even subjects, to be changed. Instead, we should allow for "telling open, partial, and relational stories. The point is not to capture the elusiveness and precariousness of our subjectivities but to develop ways to acknowledge this transience more fully" (McWilliam, 1994, p. 148). Opening the conversation to acknowledge the "slipperiness" of knowing and understanding generates opportunities for complex understandings of teaching and learning.

Keeping in mind the ethical implications associated with work that seeks transformation, "interpretation thus requires active, creative, risk-laden participation, not distanced, objective, methodological documentation, nor a pathetic, pathological withdrawal into 'my story'" (Jardine, Clifford, and Friesen, 2003, p. 61). We are implicated in the work we do, the words we choose, the research with which we align ourselves, the research with which we disagree. We are not able to distance ourselves from our work. These perspectives are our frames: "A frame surrounds an object, shapes its contours, re-presents it. Frames offer perspective; they style how an object or subject is seen. Frames imply boundaries; they limit what and how we view something" (Hesford, 1999, p. x). We need to be aware of the frames we are using. We are contextually bound beings. Making judgments is part of learning and teaching. Recognizing our reasons for making such decisions is one important aspect of becoming. A willingness to listen, converse, engage in dynamical moments with others is another part.

Through the notions of struggle, tension, and autobiographical moments, I have provided pedagogical moments in which opportunities for transformation occurred for all of us. In these moments, complex conversations bring forward ways in which pre-service teachers and I can participate in ways that allow us to be better reflective practitioners, effective professionals, and inquiring pedagogues. I believe these examples are different from what McLean (1999) considers “teacher training,” which she claims is “rooted in a set of minimalist assumptions about the competence and agency of the learners” (p. 61). She believes this image does not allow for a “vision of unique and whole persons who are actively engaged in constructing their own idiosyncratic understandings of what it means to teach, using the totality of personal understandings, through a set of complex and dynamic interactions with others” (p. 61). What does it mean to envision teacher education in a different way? What does it mean to belong together, to share experiences?

As a teacher educator, Deborah Britzman (2003) strives to recognize her work as a shared experience of co-implications. She advocates an image of teaching as dialogic:

> Teaching must be situated in relationship to one’s biography, present circumstances, deep commitments, affective investments, social context, and conflicting discourses about what it means to learn to become a teacher. With this dialogic understanding, teaching can be reconceptualized as a struggle for voice and discursive practices amid a cacophony of past and present voices, lived experiences, and available practices. The tensions among what has preceded, what is confronted, and what one desires shape the contradictory realities of learning to teach. (p. 31)

Significantly involved in the dialogic understanding is the historical situatedness of those who are struggling. Britzman’s (2003) description intertwines concerns that address the two foci of this dissertation. First, attention to a myriad of perspectives, experiences, and current research allow for complex conversations in which teachers can work towards becoming reflective practitioners, effective professionals, and inquiring pedagogues. Additionally, the commitment to the dialogic offers a (re)conceived conversation in which participants engage in struggling and collaborating about what it might mean to teach. Second, Britzman (2003) does not remove herself as an ambiguous third-person speaker but places herself among those who are doing this work. She challenges others' perspectives by bringing forward her experiences, reflections and theoretical musings about teaching. Her work inspires me to continually (re)visit what I am striving towards and who I am in this process. How I am changed and transformed occurs in conversations I have with pre-service teachers, fellow researchers, texts, and even those not in the academic arena.

My struggles continue as I pursue "fleshing out" my theories and practices about teaching and learning. Complex conversations allow me to struggle. I will never arrive at a conclusion, I hope, for complexity invites continual (re)births and transformations. The last chapter of my dissertation outlines and highlights key components for what can foster a complex conversation. This is not a set of ingredients that, if followed like a recipe, will produce a complex conversation. Instead, these components offer opportunities for multiple perspectives, possibilities, and movements. Complex conversations can maintain a structure but not have a pre-determined path or end; relationships and interactions are both a primary resource and a focus.

Chapter 5: Speculations

> So understood, the tensioned space of both “and/not-and” is a space of conjoining and disrupting, indeed, a generative space of possibilities, a space wherein in tensioned ambiguity newness emerges. (Aoki, 1996/2005, p. 318)

To speculate, according to the *Oxford English Dictionary* (1989), is “to observe or view mentally; to consider, examine, or reflect upon with close attention; to contemplate; to theorize upon,” and speculation is “a conjectural consideration or meditation; an attempt to ascertain or anticipate something by probable reasoning.” This is not a “final” chapter in the usual sense—last chapters usually contain conclusions that the author creates. I am speculating, attempting to create a tensioned space of “both and/not-and.” By speculating, I wish to imply openness, contemplation, opportunities for consideration, but not necessarily assuming what another might consider. My speculations are not the conclusion, for I believe conclusions are part of a modernist, rational logic I wish to resist. The logic I employ is different from what I term modernist. I write my suppositions as a way to encourage multiplicities, a both/and logic—not a logic of either this or that which does not allow for the possibility of both. Ted Aoki (1979/2005) qualifies the logic of either this or that as reductionistic. In his exploration for what it means to be Japanese and Canadian, Aoki (1979/2005) recognizes that one possible interpretation could be “the nondialectic *either–or* attitude” in which he becomes “totalized into either one metaphor or the other…. This totalization is reductionist in that other possible metaphors and perspectives are reduced out” (p. 347). Aoki (1979/2005) asserts that in this perspective, “one converts *a* way of life into *the* way of life. This sense-making approach is equivalent to opting for a monovision existence" (p. 347). He rejects a monovision existence for the power of double vision.[64] Aoki (1996/2005) envisions what he calls "a tensioned space of both and/not-and" (p. 318). In this type of space, one does not negate or subvert the other. In a similar spirit, I am resisting providing a conclusion, which then becomes the conclusion. I do not wish to reduce out what others may interpret in this research. So I speculate, conjecture, and theorize, in the hope that others may do the same.

In this chapter, I describe aspects of complex conversations, which include both reflective and historical dimensions of interpretations. My description of complex conversations does not advocate an algorithmic explanation, which, if followed, will produce a complex conversation. Instead, I am suggesting how to foster opportunities for multiple perspectives, possibilities, and movements. I consider this, in the context of a hermeneutical, complex form of research, to be an authentic act:[65]

> Authenticity on the part of the person carrying out hermeneutic participatory research is a self-conscious event. Researchers do not collect data in conversations and analyze data from a neutral stance. Rather, they are personally involved in the entire research project. A critical aspect of hermeneutic participatory research is reaching new understandings about an issue, problem, or question. (Herda, 1999, p. 60)

I want my research to be self-conscious. In my work, I recognize my inability to be neutral in the questions I raise, and I struggle with the ethics of teaching, along with the issues associated with

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[64] In Chapter 2 of *Mind and Nature*, Gregory Bateson (2002) experiments with the double vision and how perceptions are affected by the possibilities and limitations of what we *see*, even if it is different from what we know.

[65] Gabriel Matney (2004) questions the notion of authenticity, in the context of mathematics education discourse to reference to "real world" problems. Matney (2004) draws on the works of Heidegger to problematize the use of authentic and questions if we can ever truly know if an act is authentic.

transformative pedagogies.[66] Thus, I wish to explore how complex conversations can be a way to challenge our conceptions of self and other, theory and practice. Complex conversations invite continual (re)birth and transformations.

In this chapter, I outline ways to consider both of these concerns, in the context of complex conversations. I consider complex conversations in education, and how teaching and learning can be (re)imagined complexly. In response to the reductionist perspective for education—which I believe is exemplified in the phrase, "what works"—I propose that teaching and learning cannot be reduced to simplified, discrete steps.[67] Teaching is scholarly work, and pedagogy is a complex notion. I speculate how these ideas run counter to the trend of "teacher-proofing" the curriculum and how damaging this perception is in teacher education.

William Pinar (2004) confronts the problem of anti-intellectualism in education, and he places responsibility on curriculum theorists in higher education to provide ways to counter the "expression in popular misunderstandings of our field's mission, namely that we are to find out 'what works' and then 'apply it' in the schools" (p. 170). The imperatives set forth by Pinar (2004), to find ways to fight anti-intellectualism in education and to resist the reduction of teaching and learning to "what works," are important problematics to address. Teaching and learning involve reflexive actions and should be chosen thoughtfully and deliberately, not because someone has decided it "works." In complex conversations, we can find possibilities for teaching and learning, even potential ways of being that we do not yet know. In order to examine what complex conversations might offer for pedagogical and theoretical considerations, first I

[66] Here, I rely on "transformative" to explore how, as an instructor who works towards transformations, I do have influence in what occurs in my classroom, but my ideas and influences shift and change as I interact with students and texts. All are changed; nothing is static. My interpretation of transformative pedagogies, then, is that all are engaged in this ongoing conversation in which we are imagining the world together.

[67] Even if I did lay out the steps to follow, the results would still vary. An example can be found in baking. With the exact same recipe, each person's cake inevitably turns out differently.

examine the terms complex and conversation as a way to describe what could be interpreted as a complex conversation.

What Is Complex?

Throughout this dissertation, I continue to invoke “complex” as a descriptor for conversation. This adjective carries a particular meaning and comes out of a specific interpretative frame, namely complexity theory. The term “complexity” is an umbrella term for much work that has been performed by scientists in systems theories to explore the concepts of feedback loops, interrelationships, dynamic systems, parts and wholes as interactively involved that cannot be separated, and structures as continually renegotiated. Recognition of emergent patterns and descriptions of interrelationships become the focus of this science. Research in complexity theory offers a *New Kind of Science* (Wolfram, 2002) that can generate a different way of perceiving patterns. One consortium, the New England Complex Systems Institute, describes their perspective of complexity on their web site:

> Complex Systems is a new field of science studying how parts of a system give rise to the collective behaviors of the system, and how the system interacts with its environment. Social systems formed (in part) out of people, the brain formed out of neurons, molecules formed out of atoms, the weather formed out of air flows are all examples of complex systems. The field of complex systems cuts across all traditional disciplines of science, as well as engineering, management, and medicine. It focuses on certain questions about parts, wholes and relationships. These questions are relevant to all traditional fields. (NESCI, 2000, ¶ 1)

NECSI gives a nice synopsis of the similarities found in complexity theory research and how complexity cuts across different disciplines. Complexity theory is an emerging field in which scientists seek patterns and relationships within systems. Rather than looking to cause and effect relations, complexity theorists seek to explicate how systems function to rely upon feedback loops (reiteration, recursion, reciprocity) to (re)frame themselves and thus continue to develop, progress, and emerge.

Humberto Maturana and Francisco Varela (1987), two Chilean biologists and complexity theorists, propose that life is a complex choreography. They focus on the notion of structures as fluid boundaries that continuously change as interactions occur (see Davis, 2005). These interactions rely upon feedback. For example, the "nervous system's organization is a network of active components in which every change of relations of activity leads to further changes of relations of activity" (Maturana and Varela, 1987, p. 164). Their description incorporates feedback in the process of (re)organization and relations.[68] In addition, they propose "everything we do is a structural dance in the choreography of coexistence" (p. 248). This dance is one that is continuously negotiated through all components and aspects—a dance that moves, changes, and develops as each move, change, and transformation occurs.

Complexity scientists argue the time of Newtonian physics (mechanistic, cause-effect relations), though once considered progressive, has passed (Prigogine and Stengers, 1984; Penrose, 1989; Fleener, 2002).[69] Complex systems are defined, in part, by the interactions of the system, which include how the patterns emerge and transform what the system is. In complexity theory, the term complexity is not synonymous with complicated. The two are distinguished by the way someone interprets the system. A complicated system can be broken into parts; one

[68] Gregory Bateson (1979/2002) also examines feedback as part of a system, and he investigates how both "positive" and "negative" feedback are integral to a system's overall functioning.
[69] For more on a history of Newtonian physics and the shift to newer theories in science, see Roger Penrose (1989). Penrose (1989) categorizes Newtonian physics as part of "classical physics," which he defines as "*deterministic*, so the future is always completely fixed by the past" (p. 150). He contrasts classical theory to quantum theory and playful considerations of uncertainty, indeterminism, and mystery.

example is an airplane. In complex systems, there are no parts, only patterns that we recognize in that moment (Capra, 1996; Waldrop, 1992). The patterns mean something in relation to the entire whole, and the patterns inform what that whole might be. These wholes also have holes, depicting the fluid structures of patterns—contextualized moments that cannot be removed from the interactions without questioning the integrity of that particular moment. Thus, I intentionally use the term "complex" instead of "complicated" to describe conversation, for a complex interpretation recognizes that there are glimpses of patterns, never simple parts that are combined to create a static, fixed whole.[70] Patterns are always in flux, always in transition, always changing. Curriculum is one such pattern; mathematics is another. Teaching and learning, then, occur in a shifting, fluctuating milieu of subjects and identities.[71]

This, I believe, is where hermeneutics connects well with complexity theory and complex conversations. Hermeneutics, defined as the "art or science of interpretation" (*Oxford English Dictionary*, 1989), has shifted from a "subsidiary of theology to a general term for the study of understanding" (Herda, 1999, p. 45). This focus on understanding reiterates interpretations posed in Chapter 2 and allows for a broader (re)consideration of complex conversations in the context of curriculum and pedagogy and in the wake of defining complex. A particular aspect of hermeneutics referenced in many hermeneutic theorists' research (e.g., Ricoeur, 1991; Blomfield, 1997; Brown, 1997; Herda, 1999) is the hermeneutic circle. The hermeneutic circle has many interpretations (as befitting the spirit of hermeneutics). One definition that resonates with the complex choreography of Maturana and Varela (1987) is given by Linda Fisher (1997):

[70] In "Creating Wholes and Holes in Curriculum," I play-with language and the homonyms, "wholes" and "holes," as a way to consider curriculum as a set of uncountable possibilities (Smitherman, 2005). I draw on an image of a fractal, specifically one diagram of the Cantor Set, to depict this notion of both wholes and holes.
[71] Pinar (1998) focuses on curricular identities, not as a unitary vision but by inviting multiple perspectives from various authors to consider how curriculum and identities are interconnected and cannot be separated.

> The hermeneutic circle is, fundamentally, a dialectical and reflexive principle wherein two terms come into relation with one another, but not merely in an alternating, seesaw reciprocity, but in a progressive, mutually informing activity; the sense of circularity coming from the continual deepening and developing of the relation in what is often described as a spiraling movement. (Fisher, 1997, p. 209)

Mutually informing is the interaction of those involved in the "dance of life," as Maturana and Varela (1987) describe. Reciprocating, interacting, decentering of self—all of these are elements of a complex, hermeneutical interaction. A circle has no beginning or end.

In hermeneutics, "the two primary formulations, each a watershed in its own right in the history of hermeneutics, are the part/whole relation and the circular and presuppositional character of understanding" (Fisher, 1997, p. 208). Complex interactions do not separate parts from the whole. Instead, complex interactions necessitate both part and whole, which are momentary, contextual structures that do not remain fixed as part or whole. These interactions are part of what could be considered a hermeneutic circle, which examine "the relationship between the subject and object, the parts and the whole of language, and of history" (Herda, 1999, p. 49). Circularity is not repeating, turning circles that never change. Circularity in the hermeneutical sense is like William Doll's (1993) *Four R's*—transformative, dynamic, and interrelated, which together bring about change. Ellen Herda (1999) provides an example of a hermeneutical interpretation of history:[72]

> The historian looks at specific events over time and knows that one cannot know all the events, so the historian creatively has to supply the whole to the events in order to make sense of individual events as well as to explain the whole in relation to the part. To

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[72] This conception of history signifies the need to examine mathematics and curriculum in their historical situatednes, and our lived experiences with/in these histories.

> understand both parts and whole, they each need to be understood in relation to the other. (p. 49)

Interrelationships, as described in Herda's (1999) hermeneutic method, are fundamental to complexity science. Complex and hermeneutical are both adjectives in which interactions can be described. While these terms are not synonymous, for they are quite different in their histories and interpretative frames, neither are they mutually exclusive. Both inform each other, mutually reciprocating ways in which those who are "complexivists" and "hermeneuts" can transform their perspectives, and together can inform the complex choreography of teaching and learning.

In my first research question, I maintain that complex conversations involve multiple perspectives, and I propose the need for these types of conversations as a way to assist pre-service teachers in reflecting and inquiring. How they might reflect and inquire lends itself to a hermeneutic frame, and my inquiry thus far has contained many elements to convey a hermeneutical interpretation. In Chapter 1, I describe hermeneutical listening and its requirement to maintain an open-ended line of questioning that does not pre-set, predetermine, or pre-scribe. In Chapter 2, I elaborate how hermeneutical listening involves participants in a conversation to not have intended agendas but actually listen and consider others' comments. This type of interaction is unique and different from the current rhetoric in mathematics education. To use hermeneutical listening in the classroom is to embrace engagements in conversations around ideas, emergent within the community of learners in an open, non-linear, dynamic system of interactions, as highlighted in Chapter 3 through the works of Davis (1996), Fleener (2002), and Jardine, Clifford, and Friesen (2003). I connect their research to my own sense of pedagogical engagements in Chapter 4, which I describe as attempts of hermeneutical endeavors in which the end is not known, in playing-with, listening without intended outcomes, and perceiving connections among and between. All of these lines of reasonings come together to help me make sense of the complex conversations that can emerge in teaching and learning.

Hermeneutics as an interpretative frame describes how conversations are an important aspect of relationships in education. In this study, I continually use “conversation” as a way to imagine inquiry, interaction, and relationships. In the following section, I define what I mean by conversation, how this comes into play as a complex perspective, and how conversation lends itself to a post-modern interpretation of epistemological underpinnings and pedagogical considerations.[73]

What Is Conversation?

Today, conversation is construed as a familiar discourse, a casual talk (which I describe briefly in Chapter 1). According to the *Oxford English Dictionary* (1989), this interpretation of conversation did not emerge until the late 16th century. As early as 1340, however, the word “conversation” was used to mean: 1) “the action of living or having one’s being *in* a place or *among* persons. Also *fig.* of one’s spiritual being;” 2) “the action of consorting or having dealings with others; living together; commerce, intercourse, society, intimacy;” or, 6) “manner of conducting oneself in the world or in society; behaviour, mode or course of life” (*O.E.D.*, 1989). These three interpretations are more in the spirit for what I propose can be pursued in the classroom and in education. Primarily, the first definition, “being in a place or among persons”

[73] William Pinar (1995, 2004) writes about a “complicated conversation” with respect to education and curriculum theory. He equates complicated conversation with a curriculum that “requires interdisciplinary intellectuality, erudition, and self-reflexivity” (Pinar, 2004, p. 8) and insists the need to continue in complicated conversations if we are to have a curriculum that is alive. Further, Pinar (2004) believes that in order to complicate a conversation in educational discourse, “this practice requires curricular innovation and experimentation, opportunities for students and faculty to articulate relations among the school subjects, society, and self-formation” (p. 191). While I agree strongly with the sentiments of Pinar’s (2004) complicated conversation, I align myself with a different interpretation, with complexity theorists who interpret “complicated” as a decomposition of parts from the whole. I choose “complex,” which I believe encourages a *both/and* logic (see p. 133, this volume) of similarities and differences; contextualized, momentary parts and wholes; and, a shared, open-ended movement in which all are willing to consider transformation.

connotes a sense of the world that is hermeneutical in tone, a communion of sorts. I will use the term conversation to imply a way of being with others, a coming together to share and debate ideas.

My first encounter with defining a conversation was my intial reading of Brent Davis's (1996) *Teaching Mathematics: Toward a Sound Alternative*. Davis (1996) contrasts "conversation" from a "discussion" in specific ways: "The distinction between these communicative forms is not so much evident in the words spoken or in the topics addressed as it is the manner in which the participants listen to one another" (p. 39). He further delineates by characterizing discussion as "'coordinated action' in which the respective speakers are attempting to impose their perspectives on the other" and conversation as "less oriented to pointing out differences and more concerned with arriving at shared understandings" (p. 39). For Davis (1996), conversation is about coming together, listening, sharing, and co-emerging—a term often used in complexity science (see Prigogine, 1987; Kauffman, 1992; Johnson, 2001). Davis (1996) connects this interpretation to educational contexts in the following way:

> Quite unlike the discussion, then, the conversation is fluid, meandering its way toward a destination that is not specific, but that will be commonly known. That the destination is unspecified and unanticipated is the *strength of the conversation*, for, by being unconcerned with reaching a particular point (i.e., relinquishing the modernist desire for control)—by allowing the path to be laid down in walking—the participants are able to listen to the particularities that shape that path. The goal of the participants in a discussion, much in contrast, is often to remain rigidly in place, to be unswayed. (pp. 27-28; emphasis added)

The strength of the conversation is found in a willingness to listen without imposing a fixed end. An emergent, interpretative, interactive relationship is what makes a conversation alive. In this interaction, understanding deepens, and in that deepening, creates knowledge (p. 41).

Davis's (1996) argument for a conversation (instead of a discussion) intrigued me, and I am now cognizant of when my interactions with students, and with people in general, could be qualified as conversations or discussions.[74] His argument seems to also appeal to many of my pre-service teachers, as evidenced in their final papers that contain many references to the notions of conversation and listening as part of their teaching philosophy. The idea that there are ways in which dialogic interactions in the classroom can be conversations instead of discussions seems to excited and inspire them. Their weekly journals provide evidence of this shift, when they would describe our class's conversations (in contrast to earlier journals that used the term discussion). Their observations of the modes of listening and types of questions that occur in classrooms transform in response to reading Davis's (1996) book.

Conversation, then, in terms of being in and among others, listening, and co-emerging as shared interactions, invites creativity and transformation. Donna Trueit (2005b) draws on the notion of conversation as significant for creativity and imagination to emerge, and she situates conversation as an "act of communication, uncommon in schools, [in which] meaning is made and communities develop, as well as permeable, non-objectified, *selves*" (p. 134). As a specific form of interaction, "the action of conversation is that it plays with meaning and relations, transgresses, narrates and questions, and in so doing begins to recognize and then challenge the bounds of certainty" (Trueit, 2005a, p. 78). In playing, conversation is part of a spirit-ful experience of engagement in which life is created, imagined, emergent. Conversation is about

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[74] I use "or" in this context to mean "and/not-and" as a logical connector (Aoki, 1996/2005, p. 318). Interactions could be either conversations or discussions, or both. In the context of experience, they are not mutually exclusive.

paying attention to an "other," listening for difference, and engaging with the ideas in a thoughtful, reflective, and inquiring manner.

Aoki (1981/2005) examines the interactions and considers the reciprocities that occur in what he terms authentic conversations, which are open but not empty. He describes an "authentic conversation [as] one in which the participants in the conversation engage in a reciprocity of perspectives" (p. 228). In what I describe as a complex conversation, and Aoki (1981/2005) would depict as an authentic conversation, the

> meaningfulness of one understanding comes into view illuminated by the whole context; and the meaningful of the whole comes into view illuminated by a part. It is in this sense that I understand conversation as a bridging of two worlds by a bridge, which is not a bridge. (p. 228)

Meaning is made in-between, in retrospect, in reconsideration of what has transpired. Conversation, as complex, authentic, and/not-and emergent, is about bridging, yet not being the bridge.

One educator, John Kauffman (2004), explores a creative conversation, one that echoes these interpretations of conversation. He puts forward the idea that education today is reduced to presentation of facts; in contrast, conversation encourages dynamic interaction and creativity of thought. In both structure and flexibility, a conversation is an activity of reciprocal relations. The resulting interchange becomes a constructed pattern of interconnectivities. This is just one way in which conversation can be considered complex. Complex conversations can maintain structure but not have a pre-determined path or end; relationships and interactions are both a primary resource and a focus.

As a teacher educator, I engage in pedagogical strategies as opportunities to foster moments for complex conversations. I believe that these strategies are not remedies or bridges that others should construct. Rather, the tasks I create and implement are not-bridges—ideas that are derived from adaptations that I "borrow" from others or that emerge in response to conversations I have with pre-service teachers. One such task is the problems of the week, an activity that takes its own shape each semester. Each week different students provide a problem (usually we work with two or three problems) that everyone must attempt, then as a class we discuss approaches to solutions. In Chapter 4, I mention that this activity invites us all to struggle towards understanding. Our struggles manifest in various ways, whether in trying to understand the problem, another person's explanation, or in determining the mathematics involved in the problem. Every class seems to create its own "tensioned space" (Aoki, 1996/2005, p. 318), and by the end of the semester, we engage in a negotiated form of interaction. One semester, the students would fight over who could show another way that had not yet been discussed. A different semester, the students deferred to one person whom they termed "the math whiz" whenever they gave their explanation (instead of looking to me as the teacher for verification).

In the Spring 2005 class, I added the task of asking what mathematics was involved in the problems. My reason for asking this question was to foster the perception that while the NCTM (2000) *Standards* are tidy, compartmentalized categories of mathematical concepts, mathematics is not restricted by these artificial separations. This realization occurred for me in my participation at a conference (*Complexity Science and Education Research,* October, 2004). One attendee proposed that while we attempt to define what the stomach is, the stomach does not exist in isolation and therefore cannot be considered as a whole but as a part of a larger whole, a system. Furthermore, a system is only a part of another system, which leads to the fractal concept that zooming in or out does not reduce the complexity of a structure. In light of this perspective, then, mathematical concepts that are given as separate categories in the NCTM (2000) *Standards* are only constructs created by educators to isolate, simplify, and "ramify" (Doll, 2005). They are all parts of a whole system, namely mathematics, which is a part of a larger whole, *ad nauseum*. Returning to the problems of the week, in trying to name what mathematics was involved in the problem, the constraints of standards and categories fell away. Mathematics became connected; geometry, algebra, numbers and operations, data analysis, and measurement all mutually inform each other and work to create a rich perspective in the context of problem solving. The connections we made inspired the class to create lessons that evolve around a problem instead of around a specific standard, thereby rejecting the textbook strategy of reducing mathematics to categories that are re-presented in separate sections in distinct chapters.

I share these stories as a way to explore how emergent learning can occur, how theory influences practices, and how practices influence conceptions of other practices. The "problems of the week" activity is only one aspect of what occurs in my teacher education course. Other components of the course, including texts, journals and mathematical activities, also impact, influence, and inspire negotiated modes of being in the class. In Chapter 4, I shared a generative moment when I struggled with my students to conceptually divide fractions, but the next semester I attempted to replicate the same, without success. Thus my sharing of this emergence of rich connectedness of mathematics may never again occur in my teacher education course. I was alive with the passion that mathematics cannot be reduced to categories, spawned in the wake of my interactions with others whose interests lie in complexity theory and educational research. That passion is no longer present to the extent which it was in my classroom that semester. Therein lies a complexity for trying to create curriculum as a complex conversation, a curriculum that is alive, rich, and emergent. No attempt to imitate or duplicate the same activity will "guarantee" the same outcomes. Complex conversations can invite (re)considerations in curriculum. In the next section, I consider curricular implications for incorporating complex conversations.

Curricular Implications

Complex conversations create opportunities for education to be emergent, alive, and engaging, concepts that Ted Aoki (1986/2005) proposes in his consideration for "curriculum-as-plan" (p. 159) and "curriculum-as-lived" (p. 160). While educators create structures (plans), the curriculum that actually is lived is different from its intended plan. Aoki (1986/2005) asks educators to dwell between the two. Furthermore, he encourages educators to be comfortable with teaching and learning as emergent, and not try to control, force, or stifle how interactions might transpire. Structures exist, but they are fluid, negotiated, continually (re)considered in the moment, in the context, and in the choices made by all participants. Teaching and learning become less distinct categories, and the two collide, interact, and emerge together as a both/and experience for all involved. To be a teacher is to be a learner, and to be a learner is to be a teacher.

Complex conversations do not support the idea of "basics-as-breakdown," a reductionist method stemming all the way back to the 16th Century and Peter Ramus (see Chapter 1). Just as Kauffman (2004) argues for a shift away from the reduction of knowledge to facts, so Jardine, Clifford, and Friesen (2003) expand and explore this problematic as it pertains directly to mathematics education. They recognize that

> mathematics, as only one of the many disciplines with which schools have been entrusted, seems most amenable to the image of basics-as-breakdown. Moreover, the

> inverse is true. Mathematics seems *least* amenable to ideas of ancestry, topography, place, relation, generativity, conversation, and so on. Mathematics is "the hardest nut to crack" and has therefore become, for the authors, one of the most interesting challenges to face in an interpretive treatment of the basics. (p. 9)

Jardine, Clifford and Friesen (2003) reject the reductionist, modernist method of basics-as-breakdown. Following them, I propose that the task of engaging in complex conversations is a way to invite multiple perspectives, seeking interactions that lead to transformations, and allowing for emergence instead of controlled, prescribed conclusions. Complex conversations can lead to moments yet unknown.

Educators who invoke pedagogical strategies to invite complex conversations should consider: 1) how pedagogy is defined; 2) why we should stay away from the trend of "teacher proof" mechanisms; and, 3) move toward the notion that teaching is scholarly work. These three aspects address problematics in education today. I address each one, not as a parts separate from a whole, but as patterns that work to depict a more complex interpretation of curriculum and instruction.

Question of Pedagogy

Pedagogy is derived from the Greek tradition of schooling, places, and methods of instruction. The *Oxford English Dictionary* (1989) defines pedagogy as "instruction, discipline, training; a system of introductory training; a means of guidance;" as well as "the art, occupation, or practice of teaching; the theory or principles of education; a method of teaching based on such a theory." In Chapter 1, I define pedagogy as instructional applications and teaching practices. In my "methods" course, I encourage pre-service teachers to reference pedagogy as how their teaching philosophies and theoretical underpinnings can influence their instructional strategies, coupled with the use of epistemology for why. I ask “how” and “why” to generate moments of inquiry for all of us to reflect on our epistemological penchant(s) and how they inform pedagogical choices.

Pedagogy is not a simplistic term. Patti Lather (1991) attributes her definition of pedagogy to the work of David Lusted (1986), in which he defines pedagogy as “the transformation of consciousness that takes place in the intersection of three agencies—the teacher, the learner and the knowledge they together produce” (p. 3). Lather (1991) expands on Lusted’s (1986) definition by proposing that

> pedagogy refuses to instrumentalize these relations, diminish their interactivity or value to one another. It, furthermore, denies the teacher as neutral transmitter, the student as passive, and knowledge as immutable material to impart. Instead, the concept of pedagogy focuses attention on the conditions and means through which knowledge is produced. (p. 15)

This interpretation is in line with complex conversations, for the teacher, learner and knowledge are not parts that can be separated; rather, all must be considered in relation to each other. Intersections are the focus of pedagogy, much more than the simple, cause-effect relationship in which teacher is transmitter and student is receiver (Freire, 1970/1992).

This form of pedagogy is illustrated well in the work of Nina Asher (2005), a postcolonial feminist who teaches multicultural education courses. Asher (2005) focuses on what she calls “interstices” as sites for (re)considerations of self and other, not a separation but an integration, for “integrating—rather than resisting/distancing—one’s encounters with difference into one’s consciousness is a productive process that deconstructs the binary of self and other” (p. 1082). Asher (2005) further asserts the need for continual self-reflexive work as essential in the pedagogical process (p. 1086), and she illustrates her own struggles alongside struggles of her students. One student in particular, Jackie, recognizes that her history includes familial interactions in which differences were to be concealed, but she now realizes that "hiding differences causes more pain that recognizing them" (p. 1096). This realization is a significant one in the pedagogical work that Asher (2005) proposes. For Asher (2005), the "process of critical, self-reflexive interrogation allows White students to locate themselves at the interstices and begin understanding themselves and their stories in relation to—instead of outside of—multicultural education discourse" (pp. 1101-1102). In general, teacher educators can consider how to engage in processes of self-reflexive interrogations as a way to de-center teachers and shift the interactions in the classroom from teacher as transmitter to interrelatedness and interconnectedness.

I believe that teacher educators have the responsibility to be self-reflexive in their own pedagogical work. It is not enough for pre-service teachers to be critical, reflective inquirers; teacher educators must engage in the same endeavor. Transformative pedagogies imply that all engaged in the process will be changed. This means both teachers and students. An example of researchers who consider their own transformation in light of pedagogical practices is found in the work of Joy Ritchie and David Wilson (2000). They assert that narratives shared by pre-service teachers are opportunities for all to engage in shifts of theories, thoughts, or philosophies. As mentioned in Chapter 4, Ritchie and Wilson (2000) are teacher educators who work in the area of literacy. From their perspective, when they require student narratives, they listen, and "as we listened to the stories that we prompted teachers to tell, narratives became more than products for our consumption as teachers and researchers. They became a catalyst for revising our own thinking about teacher development" (p. 20). This pedagogical (re)consideration for how these teacher educators' ideas are influenced by the stories and theories of others is a complex interpretation. Rather than seeking to reify what they already know, they seek to be transformed in the interactions and also engage in their own self-reflexive work.

Another teacher educator, Jennifer Gore (1993), shares her *Struggle for Pedagogies*. Gore (1993) also draws attention to the work of Lusted (1986), and in her struggle, she chooses to focus on the process of knowledge production, which she envisions as the "how" in education. For Gore (1993), this

> meaning is not the same "how" of pedagogy that is often associated with "methods" courses in teacher education programs. Rather, following Lusted, it is a kind of focus on the processes of teaching that demands that attention be drawn to the politics of those processes and to the broader political contexts within which they are situated. (pp. 4-5)

Gore (1993) does not support the traditional "methods" pedagogy, which she interprets as "a limited set of techniques through which to distribute and observe individuals in order to make them responsible for their own conduct" (p. 142). Her perspective lends itself to a libratory pedagogy that works to resist mimicry as education, whether it is couched in the dominant, patriarchal discourse, or in the critical, "radical" feminist discourse.[75] Both discourses, according to Gore (1993), offer possibilities and limitations. Neither is the "answer" to all of our educational woes. In her struggle, Gore (1993) maintains that our practices suffer from our "neglect of pedagogy" (p. 156), and that as educators we need to pay particular attention to our specific practices of pedagogy.

[75] Pinar (2004) describes this form of pedagogy: "Instead of employing school knowledge to complicate our understanding of ourselves and the society in which we live, teachers are forced to 'instruct' students to mime others' (i.e., textbook authors') conversations, ensuring that countless classrooms are filled with forms of ventriloquism rather than intellectual exploration, wonder, and awe" (p. 186). As cited in Chapter 1 (this volume), Doll (1993) also recognizes the prevalence of copying in education. Trueit (2005a) expands on this concept of *mimesis*, giving its historical relevance to Western education. An acute example of this can be found in Chapter 3 (this volume), when I mention the desire for first grade teachers to be told by the textbook company how to teach from the text.

Gore's (1993) analyses of the "regimes of truth" and her own struggle for pedagogies reflect a complex conversation in which she engages in how both theory and practice work to inform our theories and practices.[76] These cannot be separated, nor can they be ignored. To struggle from the outset is a bold move, for in our modern, rational logic, we can interpret her as uninformed. In reading her complete analysis, however, one finds that she understands, but she is also inquiring and questioning. Simultaneously, she agrees with critical and feminist pedagogies, she critiques ways in which critical feminists seek to create a new meta-narrative for education.[77] By writing in this manner, Gore (1993) complexifies pedagogies in critical and feminist ways not possibly imagined, thereby transforming, in whatever small way, the discourse associated with critical and feminist pedagogies. Her pedagogy is one of questions, hermeneutical ones, questions to which she does not know the answer, complex questions. In light of these forms of complex conversations presented above, pedagogy becomes (re)imagined, more than just a method, an algorithm of instructions. Furthermore, pedagogy as a complex conversation de-centers the teacher, no longer the authority, and (re)positions the conversants in a dynamic set of interactions.

In a recent conversation with a fellow teacher educator, I was saddened by her unwillingness to resist the pre-service teachers' idea that the teacher must be the knower. This was elucidated when she mentioned she is not adept with graphing calculators and desires to know more. I responded by suggesting that she could admit this to her class and invite them all to join her in learning how to use a graphing calculator—with the idea that within scientific experiments, this would create a meaningful context for all of them. She was appalled by my

[76] I believe that Gore (1993) is doing more than complicating the conversation. She is complexifying it by considering both the potential and limitations of critical and feminist theories in the quest for pedagogy.
[77] Brent Davis (2005b) encourages the notion of simultaneity, which he believes fosters complex interactions with potential to be a rich context for educational opportunities.

suggestion and reacted that she can never be vulnerable in her methods' class, for the students would tear her apart in their course evaluations.[78] This comes from a teacher educator whose focus is inquiry-based methods in science education. I tried to share my story about my inability to conceptualize how to divide fractions (see Chapter 4 for the full story), and how we, as a class, all struggled for weeks over this idea. My story did not placate her fear.[79] Her reaction, I believe, is a typical one for many teachers. Many teachers are scared that they may not understand the information well enough to "teach" it to others. With the perspective of teacher as authority, student as passive receiver, this fear may never subside; or worse, the fear may diminish because the teacher has "figured it out" and does not need to know anything else.[80] If we ask questions and embrace open-ended conversations, what might happen in our classrooms? The concept of "teacher proof" curriculum becomes obsolete in this interpretation. If we resist "teacher-proofing" the curriculum, we must be prepared to offer alternatives and justifications.

Beyond Teacher Proof Mechanisms

In Chapter 3, I outline alternative perspectives of teacher educators who are concerned with mathematics instruction. In Charles Lucas's (1997) "Alternative Views," he follows his statement that those engaged in alternative methods involve themselves in "sustained reflection and critical analysis" perceive teaching as "an instrumental or practical art, and as such its exercise necessarily transcends or extends beyond the mechanistic application of recipes, rules, unidirectional formulas, and simple algorithms" (p. 127). One such example can be found in the

[78] I am aware that as a female academic in a patriarchal institution, she is already in a vulnerable position. Asking her to become even more vulnerable is a dangerous imposition, one that may not be worth the risk.

[79] Maybe what I mean here is to investigate how, as teachers, we can live with our discomforts and fears. I continue to have fears and frustrations as I am working. I want to work with them, embrace those discomforts, and allow them to enable me to feel more alive. These moments of discomfort and fear are opportunities to engage in critically reflecting on situatedness and influences of thoughts. bell hooks (1997) eloquently describes her movements through discomforts and fears in her critical autobiography, *Wounds of Passion: A Writing Life*.

[80] In Chapter 4, I mention that my "struggles" with dividing fractions conceptually did not seem as meaningful the second semester I challenged my class with this, for I was not struggling anymore.

work of Patti Lather (1991), who believes that "reproducing the conceptual map of the teacher in the mind of the student disempowers through reification and recipe approaches to knowledge" (p. 76). Lather (1991) works to create a different vision for teaching, one that allows for teachers and students to work together in questioning and considering how knowledge is created, who produces knowledge, and how we can work together to investigate the politics underlying knowledge production. Gore (1993) also looks to examine knowledge and critically consider who knows, what do we know, and how can we know differently and know more. Both Lather (1991) and Gore (1993) resist teaching in an imitative form.

Similarly, Donna Trueit (2005a) argues that this form of reproduction is mimetic and stems from a modern, rationalist logic of education, in which the teacher is the knower, the authority, the producer, to be imitated. Trueit (2005a) offers a (re)imagining of thought as a complex logic of relations. In this form, knowledge and understanding are co-created, co-authored, and co-shared. Herda (1999) situates learning as "associated with critique, recognizing our mistakes, and choosing another way of thinking about or doing something. This is far different from the sequential model on which most of our curricular or management activities depend for form and content" (p. 67). Learning is not sequential; why should teaching be sequential? Teaching is not imitation, reproduction, or *mimesis*, but a complex interaction in which all are both teachers and learners, playing with theories and practices, epistemologies and pedagogies.

The notion of teacher-proofing the curriculum is a critical issue in today's schooling situation. The Louisiana Department of Education (2005) has put into place the *Comprehensive Curriculum*, a series of documents that standardize and clearly delineate what objectives should be taught on what day with specific activities. Where is the teacher in this? Ted Aoki

(1983/2005) describes this as viewing the teacher instrumentally and “reducing him/her to a being-as-thing, a technical being devoid of his/her own subjectivity” (p. 115), a view he renders as oppressive. Ritchie and Wilson (2000) theorize about such ideas of “teacher-proofing” the curriculum:

> The inability to sustain a dialogue between the two [theory and practice] fosters further ambivalence toward experience and theory and compounds the confusion for preservice teachers. On the one hand, education, and the public more generally, often underconceptualize and thus trivialize pedagogy as a set of techniques anyone can master; pedagogy is encapsulated in a three-ring binder with nicely sequenced activities, ready-made questions, and an answer key…. The result is teacher-proof curricula that strip teachers of the authority that comes from an alternative and much more complex definition of pedagogy as the production of knowledge in teaching. When teaching is conceived as the active development of knowledge, as the ongoing development of careful observation, reflection, analysis, and assessment of students and classrooms—not as a bag of tricks and methods—teachers can see that theory lives in practice and practice is generative of theory. (p. 58)

This statement brings me back to Heidegger’s (1954/1977) claim that “questioning is the piety of thought” (p. 35) and that as educators, we have a duty to think. I have a friend who is an eighth grade social studies teacher in Louisiana. She personally disagrees with the *Comprehensive Curriculum* (she is an imaginative teacher who loves to create games and activities for her students), but she wonders if some students would be better off learning from a video than from some of the teachers at her school. I believe her statement is sincere and heartfelt, and I interpret her concern for students as overshadowing an annoyance that other teachers are uninvolved in or indifferent to the educational process. I think we should be outraged that a teacher could be replaced by a video, that the system has set specific structures in place that restrict curricular implementations. I also think that in education we do not demand that teachers must engage in education in lively, interactive forms, to imagine curriculum that is alive, emergent, and interactive. Revisiting the quote by Ritchie and Wilson (2000), if we as educators are going to be able to protest the notion of "teacher-proof curricula," we must demand active development and interactions that are necessary for the vitality and growth of students, teachers, and education as a whole.

As cited above, mathematics seems to be the most conducive to teaching as a sequential order of "basics" that are the foundation on which other concepts are built. This mode of instruction does not allow time or space for divergent questions. What happens if teachers open the conversation to allow students to ask questions? Jardine, Clifford, and Friesen (2003) believe

> what isn't so easy is for an individual teacher to face the question of whether he or she actually understands this mathematical "belonging together" and whether how well each beginning or experienced teacher might be able to handle him- or herself in the face of this child's question. (pp. 5-6)[81]

If teachers engage in mathematical conversations that work to decenter the teacher, then the emergence of understanding becomes shared. Jardine, Clifford, and Friesen (2003) choose to redirect this concern toward how conversation opens up opportunities for all to engage in struggling and searching, a shift in the forms of relations that occur in the classroom. Fears

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[81] One semester, I observed a pre-service teacher prepare for her mathematics class by working every problem in the exercise section of the textbook. When I asked her why she did this, she responded that she wanted to be able to already know the answer to any question a student may ask. In her journal reflection for the field experience, however, she noted that she may never be fully "prepared," and she feared that students would ask her questions to which she did not know the answer. Her frantic work to prepare, coupled with her fear of not knowing, is an example of the modernist, rationalist logic prevalent in current mathematics education discourse. Her journal reflection became an opportunity for us to engage in how, as teachers, we can work through this fear by (re)considering a pedagogy for mathematics that is more conversational and less "telling."

become part of the conversation, part of the decision-making process. The teacher does not have to act as transmitter for students; instead, the classroom can be a place where all are engaged in imagining how we can think the world together. The teacher can be a questioner yet not lose the opportunity to be a scholar.

This directly connects with teacher education, for in this form of interaction (complex conversations), narratives and histories—not pedagogical techniques—can be "placed at the center of teaching practice and the teacher education process. Attention is thus shifted away from the 'knowledge base' that teachers are supposed to acquire and 'toward the teachers and their understanding of their own teaching'" (Lucas, 1997, p. 126). Teaching and learning become intertwined, complexly related, not separate parts but patterns that connect. Learning, then, becomes the "creative act that takes place in the relationship between an event and understanding. To understand requires an interpretive act based in a risk-taking venture" (Herda, 1999, p. 137). Is the teacher educator, the classroom teacher, the student willing to take a risk? Is she willing to struggle openly? At what cost? I believe that to deny ourselves the privilege of struggling denies rich moments for transformative, complex shifts in thinking and in learning. Taking risks is difficult work, scholarly work, and, I believe, important for a living curriculum.

Teaching Is Scholarly Work

Erica McWilliam (1994), a teacher educator whose work is introduced in Chapter 3, believes the "call for teachers to intervene in their own practices has been an insistent, if historically marginalized, voice in educational inquiry" (p. 115). The question of pedagogy and the resistance of "teacher proofing" curriculum are both aspects of teacher education that need to be considered. In addition, and simultaneously with these issues, the notion that teaching is scholarly work is a pregnant idea that should be pursued. Teachers must fight for the opportunity to have input in the task of teaching and in the development of curricula as it affects their instruction.

Teaching *is* scholarly work. I did not realize the extent to which this statement resonated with my own work as a teacher educator until I heard Sharon Friesen (2005) state this, and I was moved by her ardent declaration that teaching is scholarly work. Her speech followed that of William Pinar (2005), and in his presentation he reiterated his point that teachers obligingly comply with others' theories in a position of "gracious submission" (see Pinar, 2004, p. 71; Chapter 1, this volume). Teachers do not demand often enough that what they are doing is in fact thoughtful, difficult work. In the context of both of their words, I connected the two ideas in a way that became alive for me. Teachers should demand to be part of the conversation of curricular decisions, should refuse to be "told" what to do by researchers—"experts"—and join in to offer theoretical and pedagogical considerations in education.

One of the tensions (see Chapter 4) I experience with pre-service teachers is the issue that the activities I do with my students are not ones they could duplicate (i.e., imitate) in an elementary classroom. At the end of the course, students are asked to complete an evaluation form for the university's records. These comments are anonymous, and they paint an interesting picture for what the students believe they learned or how their expectations were or were not met. I found two comments from different semesters that reveal the unwillingness of some students to engage in a (re)consideration of mathematics education, how resistant they are to my way of not teaching-as-telling.[82] (For the entire list of comments received by students, see Appendix B.) I present their words to contextualize the resistance that I experience in my classes,

[82] I wonder if some of the resistance could be related to previous success in mathematics courses. Because I ask students to engage in a literary approach to mathematics and a critical analysis of education, I am shifting the mode of interactions in the classroom away from a mode that would be more comfortable. Some people find mathematics appealing because of their belief that it is objective and does not require emotion; it is "just numbers."

not to problematize how these students are not accepting of my way of teaching but to explore how I might become a better teacher educator by listening, considering, inviting their critiques to become part of who I am. One student wrote:

> I think that because this is a "methods" class, it would help if more Methods of teaching were included. I depended on this class to learn "how" to teach math and don't feel we spent enough time on the "how" and too much time on the "why." (Spring, 2003)

This student recognizes that in the class we focused on both the how and the why for teaching. Interestingly, the course title does not contain the word, "methods," nor does the word appear on my syllabus. Students have in mind, however, what the instructor should provide in this class. As I mention in Chapter 1, pre-service teachers want to be handed, like a baton in a race, what they are to teach. Look at the Louisiana Department of Education's (2005) *Comprehensive Curriculum*. This is handed to teachers and required to be implemented. If I am going to find ways for pre-service teachers to engage in how they can function within the context of the *Comprehensive Curriculum*, I need to consider the words of this student and how I failed to consider enough of the "how."[83] I struggle with the critiques I receive from students who express their discontent. While I do not want to give into their pursuits for "what works," neither do I want to alienate them from what I believe is difficult work that can greatly benefit them as teachers.[84]

Student evaluations are part of the vita of an academic and are included in tenure portfolios. Thus, an academic's life can be made or broken by what is stated in those evaluations.

[83] In a recent article (Smitherman, 2005), I develop the idea of uncountable possibilities within a fixed boundary.
[84] Not all of my teaching has been a failure. (See Appendix B for comments from student evaluations.) Many students return to my office to share how the work in our class has had an influence in their teaching, and they now begin to understand how the work we did relates to who they are becoming as a teacher. This latent appreciation for considering teaching as scholarly work inspires me to continue encouraging pre-service teachers in their own becoming as reflective practitioners, effective professionals, and inquiring pedagogues.

The fellow teacher educator that I mentioned early reiterated this issue in her refusal to be vulnerable to students. She explicitly told me she is afraid to take risks, for they may result in her receiving negative evaluations—which directly affects her pursuit for tenure. Here is an example of how ruthless students' evaluations can be, found in another student's comments concerning my class:

> Despised this class. I didn't learn anything relevant and feel unprepared to teach math. The book used (Davis) was insane gibberish. The busy work required was an absolute waste of time that could have been used to actually teach us. (Spring, 2004)

I believe these words depict a student who was unsatisfied with my form of pedagogy. Her expectations were not met. Is Davis's (1996) book insane? What is insane? *The Oxford English Dictionary* (1989) defines insane as "mad, idiotic, utterly senseless, irrational." Maybe for her, Davis's (1996) approach to mathematics education is senseless, and my pedagogical tasks did not resonate with her conceptualization for how mathematics should be taught. I believe that what I think is important for a teacher educator can be challenged by these comments. I ponder how and why pre-service teachers resist my approach to teaching and learning, and how I might engage in self-reflexive work to reconsider my role as a teacher educator.

I search for ways in which I can change. I discuss possibilities with other teacher educators and even some previous students. One way I have changed is how I interact with my students. I focus on being more playful, more vulnerable, and I also ask in most classes how what we discuss could be "applied" to teaching mathematics. I believe the work of a teacher educator is never finished, completed, or fixed, but I also believe that the way in which I seek to influence pre-service teachers is not in vain. I desire to maintain ways to engage in complex conversations so that all of us might be changed in the interactions we have with each other. I recognize that pre-service teachers have fears and concerns, including the looming feeling of inadequacy in their preparation of becoming the teacher. I want us to become more comfortable as teachers working with-in our fears. I think our discomforts can be opportunities for us to act as self-reflexive, inquiring pedagogues. We can resolve that we do know some things but we do not have to know everything, and the teacher does not have to be the authority.

I believe Vianne McLean (1999) depicts well what these pre-service teachers perceive as their path as future teachers:

> This can best be captured in the phrase "What works?" and it encompasses much of the pragmatic decision-making that teachers do—consciously considering various practical strategies and making choices between them. This type of reflection makes good sense to many beginning teachers. It fits their conception of successful teaching as the application of "the right' or "the best" technical skill. As they accumulate more concrete strategies from which to select, their confidence in their progress in becoming a teacher is likely to increase (at least as long as the strategies appear to work when they try them out). So beginning teachers see immediate practical worth in methods courses that provide a lot of practical ideas, and give them the opportunity to try out the strategies and evaluate them. (p. 71)

Reflection as to "what works" must be more thoughtful than this, more engaged in the theories and practices of education. William Pinar (2004) attributes the disbelief that teaching is scholarly work to the pervasive problem of anti-intellectualism in education. He believes this includes the misunderstanding that as educators, we are supposed to determine "what works" and apply it to schooling (p. 170). Pinar (2004) expresses his frustration with this misrepresentation, which is further exhausted by the hostility of pre-service teachers, who

> want to study as little as possible and gain "admission" to their profession as effortlessly as possible, an especially curious demand given that they will soon, or are now (if they are practicing teachers returning for additional coursework) demanding that *their* students appreciate the courses they are teaching as opportunities to understand science, literature, etc. (p. 174)

Pinar (2004) sees the irony in their perceptions of teacher versus student. In his experience, "to require students to study curriculum as an intellectual rather than narrowly institutional or practical problem sometimes provokes that hostility" (p. 173). What pre-service teachers demand is a form of teaching that is "reduced to method, activity, and management; …a method/activity/management-as-ends model of teaching" (Ritchie and Wilson, 2000, p. 37). This type of model "reduces the complexity of pedagogical activity to a technical solution" (Britzman, 2003, p. 47). Pedagogy is much more than technique in the mechanistic, modernist, rational sense. Pedagogy invites creativity, imagination, ingenuity (Huebner, 1999).

To echo the sentiment of these teacher educators, I do not want to reduce the complexity of teaching and learning, nor do I think it is possible to reduce. Complex conversations encourage a "different way of seeing" (Genova, 1995), and a different way of imagining the world—different from a Ramist method of hierarchies, different from a patriarchal positioning of supervisors over teachers and teachers over students, and different from mathematics as what *is*.

In (re)imagining what mathematics can be, it is important to recognize how mathematics is currently construed.[85] Many mathematicians believe that mathematics is absolute, the truth, and they are certain about mathematical facts. Mathematics, however, exists for those who create, theorize, and interpret particular concepts within a fixed system as defined by the axioms

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[85] In Chapter 1 (this volume), I contrast interpretations of mathematics as created or discovered. As evidenced in this chapter, I agree with the former interpretation. I acknowledge that other may not agree with me on this point.

that create the system. Translating this to the mathematics classroom, wrong answers are the fault of the student. The truth already exists, and students are required to perform what is already known. This Platonic interpretation of mathematics infects mathematics pedagogy.

Consider, instead, possibilities of mathematics—mathematics as patterns and relationships. I believe there is a significant difference between teaching mathematics via *mimesis* and teaching mathematics emphasizing relationships and pattern—which can be seen and developed as students play with the very structures of mathematics. Learning mathematics can be rigorous, but teaching mathematics does not have to be rigid. Jardine, Clifford, and Friesen (2003) provide many examples of this. In one situation, the authors explore concepts of statistics with their fourth grade students, and what emerges is a learning experience for all. In one project,

> terms like *average* came alive for children who came to realize that their own, individual data were subsumed by the larger group. They learned that they could make some statements about the group's habits, generalizing from the data. But they also saw, especially in their anomalies, that they could not make the reverse move: use the average figure to determine what any individual had, in fact, watched that week. (p. 108)

This recognition of averages as not representative of any individual data point is a mature, insightful interpretation of statistics.[86] In this experience, Jardine, Clifford, and Friesen (2003) were awed and excited about their students' mathematical insights. The authors share that the students did not stop with this revelation but took their work even farther, to other pedagogical moments in literature from years before, and from what follows, Jardine, Clifford, and Friesen (2003) reveal "how imaginative engagement with mathematics lends power and meaning to life"

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[86] In fact, a father for two of the students is a university professor in statistics, and he "insisted that his daughters had a firmer grasp of statistics than did students three times their age" (Jardine, Clifford, and Friesen, 2003, p. 107).

(p. 108). The connections that students can make are uncountable and can be empowering. They cannot be controlled by teachers.

Mathematics should not be about control or well-performed algorithms. Mathematics and methods do not have to be scripted, pre-determined, fixed entities just waiting for us to discuss. Teaching can be imaginative, and it can be scholarly work. McWilliam (1994) poses that we imagine teaching "in terms of developing a language of possibility is to provide the conditions for a mutual examination of the many inconsistencies and contradictions in versions of teacher work generated over time and from one individual to another" (p. 110). Contrast her proposition to the way that McLean (1999) describes how pre-service teachers envision their progression into the teaching profession.

Furthermore, in the language of possibilities, a discussion about different educational theories becomes significant. Ritchie and Wilson (2000) believe without this discussion, the view that theory and pedagogy are politically neutral will be perpetuated, and teachers will continue to believe that "all that matters is whether or not 'it works in my class'" (p. 58). This pragmatic approach is not actually in line with pragmatism in the philosophical sense. Pragmatism, since its inception, adheres to the principle that theories must be tested in "real life" contexts, and "real life" informs how theories are altered, (re)interpreted, (re)imagined (James, 1907/2000; Menand, 2001; Trueit, 2005b). The notion that "what works" is what is best for a teacher is true, if the decisions being made are investigated, shared, reflected, and collaborated. The reflection is not a direct viewing in a mirror but a more self-reflective perception, one that involves questioning the "gaze," the mirror being used, and the questions being asked (see Chapter 4, this volume; Hesford, 1999; Miller, 2005). Imagining methods in this manner, not with the mindset of "give me what works," encourages educators in becoming reflective practitioners, effective professionals, and inquiring pedagogues.

Recursion

I entitled this last chapter "Speculations," for I want to present what I see as connections, patterns, emerging ideas that spring from my reading and interpretation of this study, but I do not imagine that my ideas would be exactly what yours might be. That would be deterministic and modernist, not complex, not alive. I would like to conclude with more possibilities. In this research study, my two main focal points are the use of complex conversations to influence pre-service teachers perceptions of "method," and to reflect on my own transformation as I participate in what I hope are complex conversations. I believe that, as Herda (1999) states, "unless there is a reflective and historical dimension to our thinking, it will not change how we reason and how we live out our lives" (p. 18). My work is framed (in the biological structured interpretation of frames, momentary boundaries that are fluid) with these dimensions in mind.

One pursuit is a continued conversation with pre-service teachers as they transition into their own classrooms. As they work to re-fine and re-find their own pedagogy, I would be challenged to re-fine and re-find my own pedagogy. Out of our conversations, we collaborate and create a hypertext that would not be a set of recipes but a site of possibilities for all to engage in (re)considerations of mathematics education as complex conversations, a site where we all engage in struggles and tensions for teaching and learning mathematics.

Dorothy Allison (1995), a renowned author in literature, shares how someone offered to publish her stories in hypertext. The person who proposed this idea envisioned that one story can be written "'all the way through from beginning to end. But all the way through, people can reach in and touch a word. Mouse or keyboard or a touchable screen. Every time you touch a word, a window opens. Behind the word is another story'" (p. 91). I imagine this interpretation like a fractal, for "'if you look at it from above it's just one thing, water and oil in a spreading shape. But if you looked at it from the side, it would go down and down, layers and layers. All the stories you've ever told'" (p. 91). I think this description is a beautiful depiction for the interconnectedness of stories, experiences, and language. Mathematics education has the potential to be just as beautiful.

The collaborative hypertext is continually (re)visited, (re)written, and (re)imagined. By allowing the text to be co-emergent and co-created, our words maintain a spirit of complexity, a hermeneutic open-ending. The discourse of this text is be one that nurtures conversations by asking questions to which the authors may not know the answer; challenging readers to find ways to ask other questions; leaving possibilities for other open endings; and, allowing for tensioned spaces of conjoining and disrupting (Aoki, 1996/2005, p. 318). In the words of one pre-service teacher, "*I believe students also should struggle with math concepts. It is not supposed to come easy*" (Angela, Spring, 2005). The hypertext is a space to conjoin and disrupt, to struggle and discover, to challenge and to share. May mathematics education become a field of study that allows for difference, multiple perspectives, and authentic questions, where ideas do not converge or diverge but co-emerge.

Epilogue[87]

In Kate Chopin's (1899/1988) *The Awakening*, the main character Edna undergoes a significant transformation, moving away from a mother and wife who is supposed to be the "perfect" Southern woman toward a romantically-involved, independent woman. The change is slight, subtle, yet from the beginning, there are hints of dissatisfaction, questions, and thoughts of regret. The story of Edna is a moving tale of one woman's plight to resist cultural impositions, along with a life with the expectations of others in mind. In her struggle for identity and resistance of these impositions and expectations, she alters her decision-making processes concerning who she wants to be, based on who she does not want to be. For me, this connects to Jayne Fleener and Gabriel Matney's (2005) presentation of Martin Heidegger's *clearings*, a space that is defined by what it is not.

In a similar way, my life has been a series of small changes that have led to a major shift in my current beliefs, values, and ways of being. Each choice I have made has influenced who I am becoming, as well as who I am not. One such choice was made in college, when I changed my major from computer science to elementary education. Another such change occurred when I chose to student teach in Dallas, Texas—where I would later teach—in a junior high school mathematics classroom. My mentor teacher was a great inspiration for me, and I modeled much of my teaching after her. The *Algeblocks* (Johnston, 1994) manipulatives that I still like to use, I first learned in her class. When I was given my own classroom and began developing my own way of teaching, I also attended local and regional conferences for mathematics teachers, where I gained new ideas and strategies for teaching that involved more than merely lecturing. I decided

[87] Gregory Bateson (1958) wrote two epilogues to his book *Naven*. He felt that his 1936 epilogue was sufficient at the time, but in light of theoretical work done afterward, his second epilogue reflects his shift in ideas. It is in this spirit that I am writing my epilogue, knowing my work is continuing to change even after I write this.

to teach pre-algebra in my own order, not following the textbook section by section. The mathematics coordinator hired me to write the eighth grade curriculum guide, then he requested I provide a calendar to show other teachers what section to follow on what day. This directive came from the school district, in line with issues of testing more often and wanting to ensure that students had been taught the material for which they were being tested. Though this might seem insignificant, I would argue that teachers in Louisiana who are now required to follow the *Comprehensive Curriculum* (see Chapter 5) might have a different perspective. This schismogenic relationship of teaching to testing only feeds the frenzy that is education today.[88]

At the same time as writing curriculum, I began using manipulatives in more lessons, not just *Algeblocks* (Johnston, 1994), and I strived to find more interactive forms of teaching. I recognized that not all students seemed engaged in this way of teaching. Specifically, I recall one student, one of the brightest in his class, who refused to use the *Algeblocks*, since he knew how to "do" the mathematics—which he could perform with excellence. This created another conflict in me. I prided myself in how my students were good at "doing" mathematics, but when I used other methods to teach mathematical concepts—which I thought were fun—I lost some of my students. I began to question my goal, that my students should be good at doing mathematics. (I had many students, including ESL and special education students, perform well on standardized tests.) Was this sufficient, or could there be more to teaching than students being capable of performing mathematics well?

I started graduate school in the fall of 2000, a naïve young woman who moved back in with her parents, attended church every Sunday, and maintained an extremely conservative political view. Since that time, my life has changed dramatically, though the changes have been subtle. I moved out of my parents' house when my mother tried to dictate to me what is

[88] Schismogenesis is explained in Chapter 3 (fn. 54).

considered appropriate in "courting." I became disillusioned with my participation in a Christian culture and its elitism, and eventually stopped attending church—though I still believe I am a spiritual person. I have read and learned about other ways of thinking that are different from the right-wing mindset. I believe my loss of innocence spans more than just my personal life; I have lost yet gained so much.

In the midst of all of these changes, I have also read, changed, and developed my own forms of teaching, influenced by responses and reactions from students as well as conversations with colleagues. Significant changes with respect to my teaching have formed as I am transformed through all of these interactions. I teach my mathematics methods class in a unique way—it is my own way. I resist elaborating on what I do in my classroom throughout my dissertation because I do not want to offer another way—the way—to teach. My activities and pedagogies are just that, mine yet not-mine, not static or fixed, but ever-changing, shifting, and adapting as I interact, read, and learn. I do not wish to claim that what activities I use are "what works." (See Chapter 4, fn. 53.) A colleague of mine shared an experience teaching a university freshman English literature class. Her class became extremely successful for her and her students, and her fellow faculty members wanted to know what books were on her list so they could copy it. My friend shared that the "magic" of teaching was not in the list but in the interactions that occurred in her class. Similarly, I believe that any success that may have occurred in my classroom is a result of interactions, relationships, and negotiations, not some set criteria that can be re-produced.

In this small glimpse of my own history in teaching, I wish to share how my experiences as a student, student-teacher, and teacher have influenced my philosophy of teaching and learning. I recognize that as a teacher, I have a position of authority and an obligation to prepare pre-service teachers for their own classrooms. What I choose to do with this position is an ethical dilemma. Teaching is about transforming, but who is being transformed and who is "doing" the transforming? I believe all of us can and should be learners and teachers, and that we should all struggle and be willing to consider how we are transformed in moments of interactions. I think that the tension of student and teacher is one that should continue for a lifetime, for it is in those tense moments that creativity can emerge, that struggles can lead to a growth, a transformation.

In my mathematics classroom I wish to communicate a number of ideas. As a starting point, I have five initial goals for the students, which I state in the syllabus (see Appendix C). This syllabus has undergone very few changes since its conception. What has changed is the ways in which I facilitate interactions with my students. The goals in the syllabus are open-ended and our (class) movement toward those goals is —within the bounds of the course curriculum, the course materials, and class composition—unpredictable, uncontrolled. There is no preset script, such emerges. The goals fall into two categories, both requiring engagement in complex conversations. First, I work with pre-service teachers to develop deeper understandings of mathematics, more than merely rote, algorithmic procedures. Second, I strive to interact with pre-service teachers regarding culturally influenced ideas about identity and epistemologies, and we do this through researching, conversing, listening, struggling, playing, and sharing.

Notice by my language above that I do not assert an imposed development upon them, but that together we work—as a class—to form deeper understandings. I believe that what we are doing together, in the midst of these complex conversations, differs from constructivism in an important way. In my view, constructivism imagines the student as an individual in the modernist humanist sense, as though the individual is an isolated object, without a cultural background, and only previous school or curricular experiences. This interpretation of student-centered teaching is governed by the notion that the student should "do" instead of "be told." Constructivism follows a formula of the student doing for oneself, and in this the modernist, rationalist split of teacher and student is perpetuated. The role is already set. In contrast, complex conversations embrace recursive relationships in which the system constructs knowledge, not the student. Teachers continually question their role, and this is always (re)negotiated and cannot be predetermined. I believe that in complex conversations students and teachers can create deeper meanings because they engage with the ideas of others, questioning and interacting, incorporating their past experiences and transforming them in light of new insights—in community, in the spirit of growth and discovery. Complex conversations are part of a system that is dynamic, and thoughts continue to emerge from the system.

I work around, among, and between these goals as the semester progresses. The class meets twice a week. The second day of each week, we begin with the problems of the week (POW) that the students have selected and distributed to the entire class. In our conversations about and around POW's, I invite students to share and consider multiple interpretations of what the problem is asking, what mathematics is involved (sometimes in reference to NCTM content standards), and how solutions to the problem could be approached. This opportunity for interactions can foster a sense of multiple perspectives, as well as moving towards interpretative considerations of mathematics instead of a singular, intensively algorithmic approach.

I want to mention here that though I keep sharing the activity of POW's, I do not believe it is the activity but the spirit of play that is important. There are different ways of interacting in a mathematics classroom that could solicit similar opportunities for playing with mathematics. I happen to like POW's, and it seems to work well in the context of the course. Not everyone who uses POW's in their classroom engages in playfulness. Last fall, I listened as a mathematics methods instructor presented her implementation of POW's in her course. She mentioned knowing solutions before the students were presented the problems, and she also mentioned having a preset sequence for the POW's. I would like to distinguish my "method" from hers in a few respects. First, I require my students to bring in problems for all of us to work together, which eliminates predetermining where I think the class should proceed, as well as removing a sequential order. I believe mathematics textbooks portray a specific order to presenting concepts, and the use of "foundations," "basics," and the like only perpetuate a perspective of hierarchical linearity to mathematics that is false and essentialized. Concepts in mathematics are interconnected and interrelated, and any categorization or delineation of concepts is only one way of organizing the ideas. An interpretation of nonlinearity is manifested in my pedagogy by not assuming that I can predetermine a set schedule nor believing I control the situation. I do have an influence, and I do have goals, but these are fluid in structure and interpretation for what the goals mean to me in relation to the students.

Second, as we work the problems, their grade is not dependent upon their performance in that moment. They are required to submit one problem during the semester, on the week of their choosing. (There is a sign-up sheet to distribute the problems evenly.) In class, I check each student's paper to see that attempts were made to solve the problem. Then as a group, we discuss possible solutions. The class comes to an agreement of the interpretation of the question (sometimes this is much more interesting than the solution) as well as the answer. At the end of the semester, the students must turn in their packet of correct answers, which I check. By grading their attempts as well as a final summation of correct answers, I am weighting what I believe are the significant aspects of the activity: individually considering problems without the fear of being wrong (which I believe encourages creativity and "playing with" mathematics, and recording the result of the class's conversation about the solutions (which ensures that students pay attention to the conversation).

Through our investigations of mathematical problems, our class references many different concepts. These concepts sometimes become the topics of more activities in future class activities, as thoughts and interests emerge. For example, one problem elicited a conversation about number sets, and imaginary numbers were mentioned. A couple of students asked what an imaginary number is, and instead of replying directly, I offered a bonus opportunity to investigate this question. The next week, four students shared their findings with the class. This example is not my idea of the way to teach, but a way. Other times, when a question arises, I do answer a question directly. I think the moment can encourage different ways of interacting, of teaching and learning. What is important is to always listen. This is where a dynamical interpretation for the role of a teacher is continually (re)negotiated. In Chapter 4, I shared my experience of authentically struggling with my students about conceptualizing division of fractions in the Fall 2004 class. In the Spring 2005, I was not struggling, and I felt a difference in our interactions about this concept. In the footnote following this (fn. 57), I pondered the possibility of repetition rather than recursion. This distinction is important for teaching through complex conversations. Repetition involves a recurrence of the same event with the intent of achieving the same result, while recursion is the recurrence of the same event and expecting something different.

Following our interactions with the POW, I engage with the class in an activity that involves a particular NCTM content standard. I choose activities that involve manipulatives, literature, movement, or technology, or some combination of the above. Each activity is a structured interaction about a mathematical concept, but there is no limit as to what mathematical concepts might be involved in the conversations. My expectations about what we will discuss are never the same, but there are objectives embedded in these activities which I keep in mind. (This, I believe, connects back to the issue of repetition and recursion. The same activity is used each semester, but the same interactions and responses are not expected.) For example, each semester I do a lesson involving *Algeblocks*, which I explain in Chapter 4. I start by writing two binomials on the board and ask the students to simplify, e.g., (x + 2)(x +1). The pre-service teachers can "do" the mathematics (i.e. the Distributive Property), but they only know because they learned to FOIL (First Outside Inside Last). I have yet to encounter a student who can explain why the FOIL algorithm "works." In response to my question of why, I distribute the *Algeblocks*, and we work through examples of multiplying two binomials using the manipulatives. Students begin to connect to ideas of area, multiplication, the Cartesian plane, like terms, multiplying integers, to name a few concepts. My reason for using this activity each semester is because I have noticed that most students have little to no experience in the use of manipulatives in middle to high school mathematics, nor do they have conceptual knowledge of algebra or geometry.

At the end of class, students have a reading assignment. This reading assignment is sometimes chosen by the class selecting a section from the text, sometimes selected by myself ahead of time, sometimes I assign based on the conversation that emerged in class. The students are require to write a journal that includes a reflection of what we discussed in class, summarize what they read, and reflect on the reading from an epistemological and a pedagogical perspective. We then start the next week with a discussion/conversation about the reading. I read their journals before class and try to include their thoughts and bring up their questions and comments in our conversation about the reading assignments. The journals are usually the most difficult aspect of this course for my students. They struggle with articulating their thoughts on the reading, as well as making connections to epistemologies (why this reading influences their interpretation for how one comes to know) and pedagogies (how this might manifest itself in their teaching). These journals become an essential aspect of the course, however, for I incorporate their journal assignments with their midterm, as well as with their final. They make a great text for students to reread as they work through the task of forming their thoughts about epistemology and pedagogy.

The reactions that students have to these journals seem to follow a similar pattern every semester. The first month, there is a general disdain for the task. I ask for more than just writing. I mandate quotes from texts, connections to ideas, and a fairly clear articulation of ideas. This is difficult for all of us, to negotiate understandings between their writing and my reading and interpretations of their writing. As the semester transpires, however, their attitudes begin to change. Because their journal entries can be included as part of their midterm, they revisit what they have written—which is something not often asked of students. This recursion allows them to (re)consider the readings and their responses, and it also creates a moment for them to recognize their own changes that have occurred in the course of the semester. Another comment I have received from students is their surprise about the amount of reading and writing involved in what they thought was going to be a mathematics class. This reaction fascinates me, for this usually comes from students who have been "afraid" of mathematics and are relieved that they can write about it. I believe it also reveals an assumption that in this course, students expect they will learn "how" to teach mathematics, that I will provide them with examples and they will learn particular methods. While that is part of the course, that we learn different ways of teaching mathematics, it is only part of the course. The emphasis is really on why teachers choose particular methods for teaching, and recognizing that these choices will have direct impacts on the students and the teacher. While I was a teacher in the junior high school classroom, "teaching-as-telling" was my method. I wrote my lessons in permanent ink, so I could use them again the next year. How atrocious that seems to me now! I became bored with my teaching, and reflecting back, I believe I was moving toward becoming a robot and that I would repeat the same thing every year.

Teaching and learning are part of a living system, an interactive, dynamic, complex set of interactions that occurs in an ever-changing context of knowledge, space and time. How I convey this to pre-service teachers is what I continue to work through. Complex conversations with pre-service teachers, teacher educators, classroom teachers, and anyone else who wants to talk about education stimulate new, different, and emerging thoughts that continue to inspire who I am, what I am doing, and why. I wish to inspire a passion and spirit for learning in myself and in others, that we may work together to continue thinking this world together.

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Appendix A: IRB Exemption

IRB #: 3057 LSU Proposal #:________ Revised: 04/12/2005

LSU INSTITUTIONAL REVIEW BOARD (IRB) for HUMAN RESEARCH SUBJECT PROTECTION

578-8692; FAX 6792
Office:203 B-1 David Boyd Hall

APPLICATION FOR EXEMPTION FROM INSTITUTIONAL OVERSIGHT

Unless they are qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/projects using living humans as subjects, or samples or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

Study exempted by:
Louisiana State University
Institutional Review Board
203 B-1 David Boyd Hall
225-578-8692
Robert C. Mathews, Chair

Instructions: Complete this form.

If it appears that your study qualifies for exemption send:

- (A) Two copies of this completed form,
- (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts A & B),
- (C) Copies of all instruments to be used. If this proposal is a part of a grant proposal include a copy of the proposal and all recruitment material.
- (D) The consent form that you will use in the study. A Waiver of Written Informed Consent is attached and should be completed only if you do not intend to have a signed consent form.

to: ONE screening committee member (listed at the end of this form) in the most closely related department/discipline or to IRB office.

If exemption seems likely, submit it. If not, submit regular IRB application. Help is available from Dr. Robert Mathews, 578-8692, irb@lsu.edu or any screening committee member.

Principal Investigator Sarah Smitherman Student? Y Y/N

Ph: 225-802-4085 E-mail ssmith1@lsu.edu Dept/Unit EDCI

If Student, name supervising professor William E. Doll, Jr. Ph: 578-2556

Mailing Address ~~223~~ 223 Peabody Hall, Dept of C&I, LSU 70803 Ph________

Project Title Reflections on Teaching a Mathematics Education Course

Agency expected to fund project n/a

Subject pool (e.g. Psychology Students) Elementary Education Students

Circle any "vulnerable populations" to be used: (children <18; the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

I certify my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted.

PI Signature Sarah Smitherman Date 6/21/05 (no per signatures)

==

Screening Committee Action:

Exempted ✓ Not Exempted ________ Category/Pargraph ________

Reviewer TROUSDALE Signature Ann Trousdale Date 9-11-05

Appendix B: Student Evaluation Comments

EDCI 3126-4, Spring 2003

"I think that because this is a 'methods' class, it would help if more Methods of teaching were included. I depended on this class to learn 'how' to teach math and don't feel we spent enough time on the 'how' and too much time on the 'why.'"

"I suggest more activities that we could actually use in the classroom. Instead of focusing on preparing us for grad-school, focus more on preparing us for the classroom."

"This class was very interesting. Sarah made us see that we should know the theories behind the mathematical concepts we teach. It really makes me feel prepared to go to grad school."

"Class is excellent. Keep it like this in the future. Davis and Wiley books are great and helpful for the future."

"I really have now a lot of good ideas of different ways to approach math and a better understanding of how I feel about it, but I still don't really feel prepared to teach it."

"Even though I hated the Davis book at first I think your pushing us to keep on will truly benefit us in grad school. Please do more math examples like the Cartesian plane. Also break up Davis and other book so not all at once."

"Sarah made this course very enjoyable. I used to be really wary of math, but she helped me realize the potential we all had to teach it!"

EDCI 3126-4, Spring 2004

"We always knew what we were being graded on; she provided plenty of rubrics and guidelines. I adored her!"

"Great class but too much writing involved."

"Awesome class, awesome instructor. Best class I have ever taken at LSU."

"Despised this class. I didn't learn anything relevant and feel unprepared to teach math. The book used (Davis) was insane gibberish. The busy work required was an absolute waste of time that could have been used to actually teach us."

"I learned a lot in this class and I think that it really prepared me for graduate school. Mrs. Smitherman is very willing to provide outside help and assistance. I can tell that she really cared about us. She was very professional during the semester even after some things went wrong. She is a great teacher."

"Fabulous class! Thank you."

EDCI 3126-2, Fall 2004

"Great course, love the focus on theory and class discussion. She practices what she preaches, so to speak – uses the techniques she's teaching us about to teach us those techniques. (Does that make sense?)"

"Ms. Smitherman was extremely knowledgeable about this topic; yet, she explained things to me in a way that really made sense. I learned a lot and feel better prepared for student teaching."

"Ms. Smitherman is a great teacher. She really encouraged me to struggle with math concepts so that I can more effectively explain them to students. She was kind and always considered our input. She was flexible but in control. Great class!"

"I would have liked to have lessons modeled."

"She was willing for outside, very organized, and enthusiastic. Thank you!"

"Great class! I really enjoyed this class. Highly recommended class and teacher."

"Ms. Smitherman was always willing to help out inside and outside of class. She was knowledgeable and exc ited about the material. Great teacher!"

"Very nice."

"I learned more in this class than in any of my other methods classes."

EDCI 3126-3, Spring 2005

"Ms. Smitherman is very enthusiastic about teaching math. Only complaint was the amount of work she kept piling on."

"The Reys book could have been used more. Other than that, I learned a great deal from this course. The teacher was really informative and enthusiastic about the subject."

"Mrs. Smitherman did a good job at encouraging us to think about math outside the box. Davis was good but the Reys book was used less."

"An excellent class. I learned so much in this class and this class will be by far the most useful class I ever had. You taught me how to teach and learn math in new ways."

"I absolutely loved this class! I could not have learned any more. You have given me a new and improved way of thinking about teaching and math; thank you…. Good luck with everything. ☺"

Appendix C: Course Syllabus (Sample)

EDCI 3126: Curriculum Disciplines: Elementary and Middle School Mathematics

Instructor: | **Home Phone**:
Email: | **EDCI Dept.**:
Office Hours: | **Office**:

Catalog Description (*3.0 credits*)
2 hours lecture, 2 hours lab/field experience in multicultural settings. Structures of scientific disciplines for teaching lower/upper elementary and middle school mathematics; instructional strategies, techniques, basic rationales, and materials.

Course Goals and Purpose
EDCI 3126 is one of the core curricular discipline courses taken after EDCI 3200 (Reading, Writing, and Oral Communication) and EDCI 3127 (Elementary and Middle School Social Studies), and prior to the formal student teaching experience. *Concurrent enrollment in the same section of EDCI 3125 (Elementary and Middle School Science) is required*, since there are numerous crossovers in terms of pedagogy, fieldwork experiences and supervision.

This course explores mathematical concepts that are the foundation for students' understandings of mathematics. Specifically we will explore these concepts as to why they are significant (epistemology) and how they can be taught (pedagogy), using Brent Davis' (1996) *Teaching Mathematics* and the National Council of Teachers of Mathematics (NCTM, 2000) *Standards* as vehicles for exploration. This course will involve discussions of both theoretical and practical applications in mathematics education. The four week field experience component of this course offers students a real-world public school experience in order to develop as critically thinking and self-reflective educators.

Specific course goals include:

1. to develop a continual self-reflexive awareness of teaching that critically analyzes instructional choices and the current location of student understandings, and to seek to constantly improve the why and how of the pedagogical strategies implemented;
2. to learn a variety of modeling and pedagogical strategies (including technology) so as to teach elementary and middle school students mathematical concepts in a way that enriches their learning experience;
3. to integrate mathematical concepts with other curriculum disciplines, such as children's literature, art, and science;
4. to improve personal understandings and attitudes towards mathematics; and,
5. to plan assessment strategies that will generate indications of students' mathematical understandings.

Field-Based Experiences
Field-based experiences are intended to provide the opportunity to hypothesize and reflect upon methods and strategies explored in class, and to adapt the students' beliefs to the realities of elementary classrooms. Each student must spend a specified amount of time in an elementary or middle school classroom leading whole-group math lessons, as well as working with individuals

or small groups of children as needed. EDCI 3126 students work in pairs, so that a peer is always available to provide feedback through observation and written reflection. Failure to complete the field-based experience adequately means failure to successfully pass this course.

Class Materials

Required Texts:

Davis, Brent. (1996). *Teaching mathematics: Toward a sound alternative.* New York: Garland Publishing. [ISBN: 0815322984]

Reys, R., Lindquist, M., Lambdin, D., Smith, N., & Suydam, M. (2004). *Helping children learn mathematics, active learning edition with field experience resources. 7th ed*. New York: John Wiley & Sons. [ISBN: 0471151637]

NCTM. (2000). *Principles and standards for school mathematics*. Reston, VA: Author. Retrieved online on January 12, 2004, from http://standards.nctm.org/document/index.htm.

Recommended Text:

American Psychological Association (APA). (2001). *Publication manual of the American Psychological Association. 5th ed*. Washington, DC: Author. [ISBN: 1557987912]

Course Requirements and Evaluation

Journal	30%
Quizzes	10%
Field Experience	20%
Class Participation	5%
Midterm	15%
Final Exam	15%
Problem of the Week	5%
Total	100%
Bonus	

Grading Scale:

A	93-100
B	85-92
C	77-84
D	70-76
F	69 *or below*

Journal (30%):

A reflective journal is required for this course. A schedule for journal entries will be provided. Each journal entry is to be emailed to the instructor through Semester Book and must be received prior to the beginning of class. Any late submissions will have points deducted. The following header is to be used:

Name
Journal Entry #
Reading(s)
Prepared for (*due date*)

The student is to record and will be graded upon the following components (at least one paragraph for **each**):

1. Summary of the classroom discussion;
2. Reflection (this means personal opinions and self-critique) of the classroom discussion;

3. Summary of the reading assignment **for the next class;**
4. Reflection of the reading assignment from a *theoretical* viewpoint, including at least one quote (APA style) from the text;
5. Reflection of the reading assignment from a *pedagogical* viewpoint, including at least one quote (APA style) from the text; and,
6. Any questions that arise from the discussions, readings or self-reflections that may need to be addressed.

Each journal entry is to be free of grammatical errors and spelling mistakes. Points will be deducted from assignments where the quality does not meet these standards. Also, all citations are to be correctly done in APA style. The journal entry may be sent as text in an email or as an attached document.

This journal is to be kept throughout the course, including *during* the field experience. Reading assignments will be given via email while you are in the field, and you are responsible for all assignments that I send to you.

Quizzes (10%):

Quizzes will be administered throughout the semester and will cover topics from the textbook, class discussions, video presentations, and lab projects. They may be given at any time during class time.

Field Experience (20%):

This component is comprised of four parts: a unit plan, a journal (this is separate from the personal reflective journal), partner feedback, and corrections. You will not be graded upon how successful your lessons may be but as to how well you critically analyze the theoretical and pedagogical issues that arise as a result of your teaching.

1. Unit plan – prepared by each pair

   Included are six (6) lessons, age appropriate, and will be graded according to a rubric developed by the class prior to the field experience. The initial set will be submitted to the instructor prior to the field experience orientation day, and the final set will be submitted, with corrections and adjustments, after the field experience is completed.

2. Journal – prepared individually

   Each journal entry (there are to be 6 total) must be typed, in paragraph form, and should include at least two things that went well during the lesson, two things that could be improved or changed and how they would be changed, and what you learned as a teacher. Each entry is due the day of your next teaching experience. (I will come to the schools and collect them, then return them in the class folder located at the school.)

3. Justification paper – prepared by each pair

   Each pair is required to provide a paper that explains the epistemological underpinnings and pedagogical strategies that the lesson plans employ, and this paper should accompany the final lesson plans of the field experience.

4. Partner feedback – prepared individually; 2 copies are made (one for partner, one for instructor)

    Each partner is to compose at least a two paragraph note (three times total), first stating two things that what went well (be specific), and second stating two things that could be improved (be very specific and constructive). Remember to keep in mind the course objectives, addressing both theoretical and pedagogical issues.

Class Participation (5%):

Attendance for class and lab is expected. Participation in class discussions is also expected. Anyone who is not actively engaged in the course to the satisfaction of the instructor will be notified of their lack of participation. Class participation points will be awarded each class, and a final total will be calculated at the end of the semester to comprise the 25 points/5% grade.

Midterm (15%):

The midterm will be a two part essay which is to be prepared outside of class. Each student will submit a question for the midterm. The midterm will be due Monday, October 5, 2004. A rubric for grading the midterm will be developed and distributed prior to its due date.

Final Exam (15%):

The final exam is scheduled for Thursday, December 9, from 7:30 a.m. – 9:30 a.m. The final exam will be comprehensive and will be an assessment of students' knowledge towards particular mathematical teaching strategies, lesson development, epistemological viewpoints, and pedagogical insights that emerged as a result of this course's texts and class discussions. The form of assessment given will be developed and determined by the class prior to the final exam.

Problem of the Week (5%):

Students will be required to compile the set of problems of the week created by the instructor and fellow classmates. Two students each week will submit a problem electronically to the instructor on that Tuesday. Each student is expected to bring a written solution to the two problems in class on Thursday, which will be initialed by the instructor during class time. At the end of the course, each individual will be assessed according to the submission *and correct solutions to all* of the problems.

Bonus:

Opportunities for students to earn bonus points will occur during the semester, as determined by the instructor. Be ready!

Vita

Sarah was born in Baton Rouge, Louisiana, but moved to Texas to attend undergraduate school and to teach. After living in Texas for 10 years, she somehow found her way back to her hometown, yet returning with a purpose. Her time spent in graduate school has been so much more than an academic exercise. She has made remarkable transformations in her identity, politics, spirituality, and relationships. These are all areas in which she hopes to struggle for the rest of her life. As she transitions a new phase in life, she will take with her all that she has learned, all the memories of conversations, and hold dear the beauty, tranquility, and solidarity that exists in the Curriculum Theory Project at LSU and that exists in Baton Rouge.

The experiences shared in Texas with teachers and students, as well as those shared with fellow graduate students and professors in Louisiana, will live on in her thoughts and memories. Even though this time together is no longer, she will strive to maintain the relationships that have been formed. She hopes to travel both nationally and internationally with colleagues and friends, to play and explore life elsewhere and everywhere. Through all that life holds, she looks forward to sharing it all with her significant other. The journey has only just begun!