Spring 5-17-2019

Doing Science: Data Enactments in Mathematics Education and Qualitative Research

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ACCEPTANCE

This dissertation, DOING SCIENCE: DATA ENACTMENTS IN MATHEMATICS EDUCATION AND QUALITATIVE RESEARCH, by SUSAN OPHELIA CANNON, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education & Human Development, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

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SUSAN OPHELIA CANNON

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Myers, K., & Cannon, S. O. (2018). Looking inward: (Re)negotiating and (re)navigating mathematics teacher beliefs as teacher educators, students and scholars. In T. Hodges, G. Roy, & A. Tyminski (Eds.), *Proceedings of the 40th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Greenville, SC: University of South Carolina & Clemson University.

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DOING SCIENCE: DATA ENACTMENTS IN MATHEMATICS EDUCATION AND QUALITATIVE RESEARCH

by

SUSAN OPHELIA CANNON

Under the Direction of David W. Stinson, Ph.D.

ABSTRACT

Leading mathematics education scholars have called for different theoretical possibilities (Stinson & Walshaw, 2017) and broader considerations of what "counts" (D. B. Martin, Gholson, & Leonard, 2010) in mathematics education research. This study—situated at the intersections of statistics education, mathematics education, and qualitative inquiry—responds to these calls through an intellectual exploration of Karen Barad's (2007) readings of Niels Bohr's philosophy–physics and her questions of what it might look like to do science while valuing both objectivity and posthumanist accounts of reality. The study considers how taking up data with different theories and methods in mathematics education research produces different knowledges and the ways this rethinking opens up different possibilities for school mathematics.

To bring clarity to the theoretical exploration, mathematics teaching and learning at the classroom level was examined. Two middle school mathematics teachers who taught a 10-week mathematics enrichment course Mathematics and Current Events were observed and interviewed. During the course, teachers and students researched provocative topics in the media

and considered the ways in which mathematics interacts with how they understand the world. The course focused on the statistics that are presented by the media and the ways that citizens might use mathematics to make meanings of important problems. Observation and interview data were mapped to aspects of statistical literacy (e.g., Wild & Pfannkuch,1999) informing practice in middle grades classrooms and bringing questions forward for consideration about how critical dispositions of statistical thinking might be developed in middle grades mathematics classrooms.

The theoretical exploration of the diffraction (Barad, 2007; Haraway, 1992) of interpretivist and poststructuralist readings of the data illustrates that different theories and broader considerations in mathematics education research can open up important new spaces in the field of mathematics education research. Shifts in what is legitimized in the field of mathematics education research makes cracks in hardened places in the field that can provoke new questions and, in turn, new methods. In the end, different theories and ways of knowing allow diverse ways of doing science and broader views on what gets counted in knowledge production.

INDEX WORDS: Mathematics Education, Statistics Education, Qualitative Inquiry

DOING SCIENCE: DATA ENACTMENTS IN MATHEMATICS EDUCATION AND QUALITATIVE RESEARCH

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A Dissertation

Presented in Partial Fulfillment of Requirements for the

Degree of

Doctor of Philosophy

in

Teaching and Learning – Mathematics Education

in

Department of Middle and Secondary Education

in

the College of Education and Human Development
Georgia State University

Atlanta, GA
2019

DEDICATION

This dissertation is dedicated to my participants, all past and future students, and my children.

ACKNOWLEDGMENTS

As many have said before me, all the makings of a text of this length cannot be traced. I have had the privilege of writing and thinking with brilliant scholars, I have tried to live together well with those around me. I have been supported in countless ways, all of which cannot be named here.

Given that this dissertation, depends on my reading of Barad, I specifically acknowledge those with whom I have read her texts. I first read Barad in a reading group with two of my committee members in 2016. I reread and took notes on parts of the text as I completed my comprehensive exams, and I read *Meeting the Universe Halfway* a third time with Maureen during the writing of this dissertation. We met weekly to discuss a chapter at a time and had far reaching conversations about Barad's proposals and how we thought they connected to our research and our lives. Josephine listened as I rambled on about Barad over countless home cooked lunches, and Joe listened to me as I connected her ideas to everything we encountered together. Travis and Jenni and Kayla are also present in these writings. My readings of Barad are influenced by all of these conversations and by all of the scholars whose interpretations of Barad I have read and considered. Texts do not sit still. Meaning does not sit still.

This dissertation was produced in intra-action with David W. Stinson who took me on late in my program despite his already full plate and challenged me and trusted me equally. He also asked Elizabeth de Freitas to join us; and I feel so fortunate that she graciously accepted as her wisdom and insight were priceless at my defense. Stephanie Behm Cross brought me into doctoral work and supported me in countless ways over the past five years from mentoring me as a teacher educator to helping me navigate my many indecisions. Teri Holbrook endured and extended my academic joyrides and pushed me in my writing. Sarah Bridges-Rhoads was the person I could walk with and talk around any theory and feel that I understood it better at the end. I have laughed and cried with all of my committee members. I think we have lived together well in this adventure (also see Appendix I).

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PROLOGUE

> The concept of philosophy as that which is located on the earth, at its surface, in the cosmos, part of the universe, worth no more nor less than any other part, this image of the philosopher as one who lives and develops a knowledge of how to live well, traces a movement that will be continually displaced by dualism but also reasserts itself from time to time in the history of philosophy that follows from it.
>
> – Grosz, 2017, p. 22

This dissertation, in part, accounts for my grappling with how to live well while doing science and philosophy in the academy. Simultaneously, it works to flatten and pull into closeness data, theory, practice, method, material, the ethical, and the political. These projects are not finished, and I expect will never be finished, they go on and on as relations change. Yet, the dissertation as a product has boundaries, it has to sit still for a moment. Holding things still and drawing boundaries about what is necessary is a challenge for me, so I hope you will bear with me as this dissertation will at times go astray.

My dissertation committee chair kept saying to me when we reviewed my initial full draft— This is a dissertation. This is a dissertation. This is a dissertation. Work with this. He knows me.[1] He knew that if I started to question it or tie it to some other strings it might fall completely apart or go up in smoke. This dissertation is a knowledge making apparatus[2] that was

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[1] I know that this screams stable humanist subject. My poststructural readings remind me that there is not an essential me to be known, yet I do not deny that I still think in these ways, and that these ways of thinking can be comforting. I find it useful to put these words on the page at times, the ones that I usually question and censor and cross out to adhere to my theoretical agreements.

[2] I will not fully explain all of the terms that I introduce in this opening section, as I will elaborate on them later, but I will provide quotes from Barad in the footnotes to which the reader may refer to tide them over until these concepts are taken up again. Here is Barad (2003) on apparatuses:

constructed in configuration with my committee, the fields[3] within which I was reading, writing, and working, and the material aspects of my life.

As I will explain in more detail later, all knowledge making apparatus enact cuts.[4] In Barad's view, agency is distributed across the apparatus, and each part counts in the ongoing production. Yet, not everything that matters in the making can be included, listed, or considered. Linear cause and effect relationships between discrete objects become unthinkable. In the making of this dissertation, cuts[5] have been enacted by others and by me to make it more digestible. This text was not enough, and it was too much. Cuts were made to make this dissertation a finished product if not a finished project.

I have produced a five-chapter dissertation. Despite my predilection for crossing fields, pulling threads, disrupting texts, and other odd movements in relation to the norms of the academy, I made the decision to write this dissertation in a (mostly) traditional five-chapter format, although there are certainly times when the content of particular chapters exceeds the boundaries or crosses back and forth into other chapters. By structuring in a more conventional

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> Apparatuses are not inscription devices, scientific instruments set in place before the action happens, or machines that mediate the dialectic of resistance and accommodation. They are neither neutral probes of the natural world nor structures that deterministically impose some particular outcome…. apparatuses are not mere static arrangements in the world, but rather apparatuses are dynamic (re)configurings of the world, specific agential practices/intra-actions/performances through which specific exclusionary boundaries are enacted. Apparatuses have no inherent "outside" boundary. This indeterminacy of the "outside" boundary represents the impossibility of closure—the ongoing intra-activity in the iterative reconfiguring of the apparatus of bodily production. Apparatuses are open-ended practices. (p. 816)

[3] Chapter 1 will explore fields in detail.

[4] "This is not a static relationality but a doing—the enactment of boundaries—that always entails constitutive exclusions and therefore requisite questions of accountability" (Barad, 2003, p. 803).

[5] "Intra-actions enact agential cuts, which do not produce absolute separations, but rather cut together-apart (one move)" (Barad, 2014, p. 168).

format, I recognize that I am making a cut that perhaps legitimizes this research and at the same time works against the opening of space for alternate formats. My committee did not discourage me from taking risks with format, and I have broken some of the formatting traditions. I tried to do this discriminately and to consider the cuts that each formatting decision made for the reader-dissertation-researcher apparatus. I attend to structure and convention of the fields, so that I can be recognized as a part of them while making smaller cuts that can work to radically reconfigure the field. By maintaining the format and simultaneously breaking it, I make a cut together-apart.[6]

It is also my hope that this dissertation as part of the mathematics education research phenomenon[7] unsettles or causes movement or re-turning of ideas about what mathematics education research should or could look like—about what counts as research in this field—another cut together-apart. A differencing in the field of mathematics education that enacts a boundary and pulls into closeness. My adherence to particular structures and conventions[8] of dissertation and the field provides a rhythm and expectation of what should come. And from there a gasp can follow, a recognition of difference. It is a rethinking of difference that is the work of this dissertation. Curiosity at difference rather than judgment, I invite a joyful perplexity at difference—wondering at what difference might offer, what it could do. As you move through the dissertation, again I hope that you might take note of the surprises, the gasps, or the sighs.

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[6] *Agential separability* – "the agentially enacted material conditions of *exteriority-within-phenomena* – is what agential cuts enact in their cutting together-apart" (Barad, 2012, p. 177).

[7] "In particular, apparatuses provide the conditions for the possibility of determinate boundaries and properties of 'objects' within phenomena, where 'phenomena' are the ontological inseparability of objects and apparatuses" (Barad, 2007, p. 127–128).

[8] As an example of a taking up of conventions, I use the term interpretivist in describing part of my research. The way that I use the term aligns with the traditional use of the term in mathematics education, though it conflicts with the ways in which that term is taken up and used in qualitative research. In doing so, a cut is made that might make me-this dissertation-knowledge more legible and recognizable to mathematics education researchers and less legible to qualitative researchers.

These moments are signaling that boundaries have shifted or stretched, a tentative, or perhaps bold, reclamation of territory in the field or a least a recognition of the edges.

As a way to orient you as to what will follow in this dissertation and introduce you to some of the concepts that ground it, I connect the spacetimemattering[9] of the end of this dissertation project (this product, this text), to the spacetimemattering that began[10] this project (a meeting with my committee to discuss my comprehensive exam questions). I invite the reader to come into contact with this text that takes on the guise of stability and to actively resist the idea of it as stable. Think with it, pick it up. Turn it over, re-turn it. Connect, distance, and align. I offer this invitation with the acknowledgement that the ideas laid out in this dissertation still shimmer and shake.

The reading map, intra-action, and specific material arrangements. For the comprehensive exam meeting in December of 2017, I remember that I was determined not to present one truth of myself or to play at pretending that all of the things that had come before or ended up outside of comps did not matter. I felt a sense of responsibility to account for all the

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[9] I provide two quotes somewhat at length here as this concept is not discretely defined that I can find. The first quote is from an interview with Barad;

> Being attentive to ways in which we are re-doing, with each intra-action materially re-doing the material configurings of spacetimemattering. The past and the present and the future are always being reworked. And so that says that the phenomena are diffracted and temporally and spatially distributed across multiple times and spaces, and that our responsibility to questions of social justice have to be thought about in terms of a different kind of causality. (Dolphijn & van der Tuin, 2013, p. 68)

> As such, I want to begin by re-turning—not by returning as in reflecting on or going back to a past that was, but re-turning as in turning it over and over again—iteratively intra-acting, re-diffracting, diffracting anew, in the making of new temporalities (spacetimematterings), new diffraction patterns. (Barad, 2014, p. 168)

[10] I acknowledge that time is not so linear, but in the academic apparatus within which this was produced, comps are the beginning of the dissertation trajectory and the defense is the end. Besides I think that there are some interesting lines to be drawn between these two events.

readings I had been thinking with, all the authors and philosophers that mattered in my thinking. Therefore, I laid out all the texts on my kitchen table and spent days weaving quotes and concepts from them onto a map (see Figure 1). It mattered to me that I accounted for all of the readings that had mattered, in whatever way.

The connections among the ideas were not singular or unidirectional but were instead sprawling and brambly. Although they were static in the drawing, they evoked movement and gesture. In looking back on this move through Barad's concepts, I see this as an accounting of the specific material arrangements[11] of my knowledge making up to that point and a gesture toward the intra-action between the concepts and texts. Barad asserts that there are not determinate boundaries between objects, but that boundaries are enacted in phenomenon. At the time, I resisted the cutting off or out of the readings that were not going to matter in or beyond comprehensive exams. I wanted to acknowledge and account for them as part of what led to my thinking/being in that moment.

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> Objectivity is about being accountable to specific materializations of which we are a part. And this requires a methodology that is attentive to, and responsive/responsible to the specificity of material entanglements in their agential becoming. The physical phenomenon of diffraction makes manifest the extraordinary liveliness of the world. (Barad, 2007, p. 91)

Figure 1. Map of readings and concepts.

In this dissertation project, you will find an accounting for the specific material arrangements of its production. I begin in **Chapter 1** by taking up the question of academic fields, how they are produced, and the movements across and between them. I describe my propensity for field crossing and the ways that these crossings move me and my writing/thinking. I consider how fields are formed and maintained and the affordances of moving across fields and of structures within fields. In **Chapter 2**, I more specifically introduce two of the fields across which I am working: statistics education and mathematics education; and consider how particular theories have been used by other researchers to shift these fields. I provide limited but focused examples of shifts in the field of mathematics education research due to the use of poststructural theories and methods. Then, I explore new materialist theories and how they have been and could be employed in statistics education, mathematics education, and qualitative inquiry. This attention to fields and the place(s) from which I am working is an acknowledgement of both intra-action and specific material arrangements.

Enacting cuts and boundaries. Though I attempt to account for the fields within which I was moving and the readings that impacted my thinking, this accounting was always already partial. Of course, things were left out: readings that were forgotten, materials that were taken for granted, lines that were not drawn that could have been. There are always cuts in accounting.

In the comprehensive exam meeting, my committee and I talked extensively about how my dissertation/comprehensive exams might intra-act with the map. We imagined how an overhead transparency (the clear 8 ½" x 11" sheet) overlaid on the map could create boundaries of what I would focus on while still respecting or having some responsibility to what lies outside or beyond it.

Figure 2. Cut one

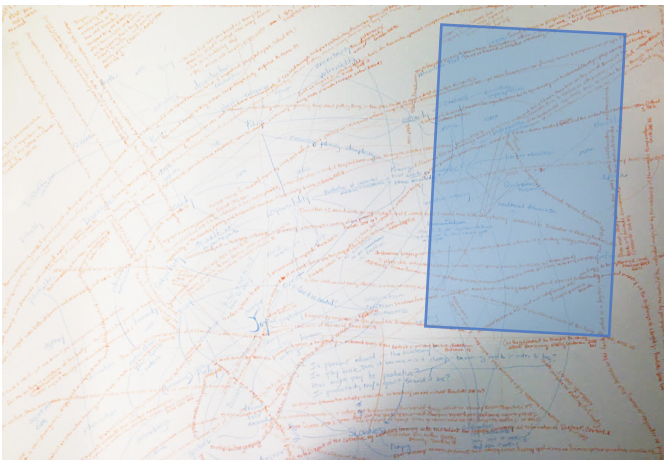

Figure 3. Cut two.

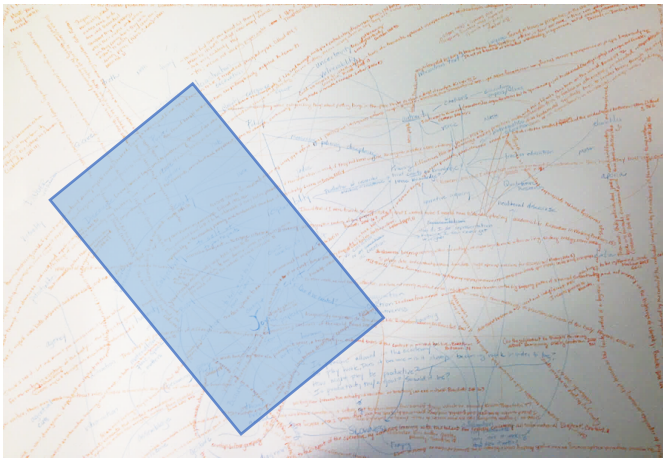

Figure 4. Cut three.

Even with this still partial accounting of my readings, this boxing in allowed me to feel that I could zero in on particular details in considering the questions and focus of my comprehensive exams knowing that they were tied out to other important ideas. It also prompted further questions: How does it matter where I enact boundaries around my research? What is included what gets left out? What cuts are made of which I am not aware? How do the more than human intra-act in the production of boundaries and cuts? Some of these cuts are intentional and easily recognizable. Other cuts are less noticeable, or their effects might not be recognized until

some time has passed. Attention to the specific material arrangements and the enactment of boundaries is essential to Barad's objectivity which is a focus of **Chapter 3**. In that chapter, I describe the methodological moves made in the production of this dissertation and account for the marks that I think these moves made on bodies. I discuss the material and theoretical interruption that led to the shift in the becoming of this dissertation and the iteration on that study. Then I map Barad's objectivity and the diffractive methodology was central in this project.

Scrolls of paper and diffraction. In looking back to the comprehensive exam meeting, I can draw a line to the beginnings of my thinking with diffraction and difference. In that meeting in which I imagined my committee and I would decide where/who I was becoming as scholar, I brought all the materials that seemed to matter—books, the music I listened to while writing, writings from across my three years, self-portraits I had produced across the months leading up to the meeting. I hung all my writings under self-portraits. I pinned trace paper over the portraits and the writings (see Figure 5). Some writings were linear and academic, others were experimental. How did those differences matter? Somehow I thought then that if my committee and I could read across these papers, we would be able to figure out who and what I was becoming as a scholar or what difference it made to write in particular ways.

In the production of my dissertation, the idea of how differences in knowledge production mattered became central. I wanted to consider how producing knowledge differently, constructing different apparatus of which I was a part, would matter for the knowledge that was produced and ultimately for students in schools.

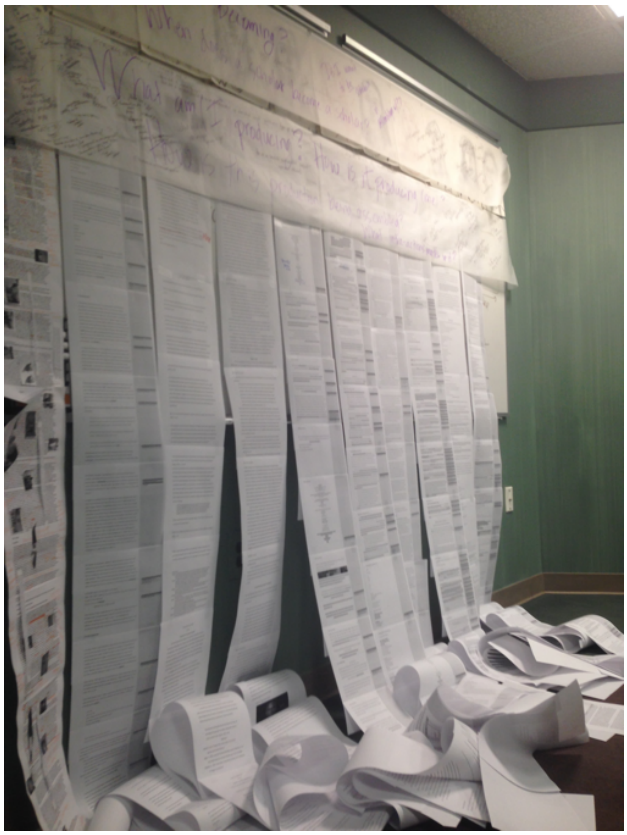

Figure 5. Excess—December 2017.

Chapter 4 details two knowledge making practices that produced two data[12] enactments that I then read through each other. I printed them out, taped them together, and laid them through my living and dining room along with printed transcripts of interviews with both participants (See Figure 6). I listened to the audio of the interviews as I read the enactments across each other. I wanted to see what I was producing; what knowledge was being made in these phenomena. As I read, I was surprised at the knowledge that was produced through these practices and what got privileged, what got left out.[13] Reading across made differences more

[12] Throughout, I use the term *data* as both singular and plural for reading ease.

[13] Of note, a story that my participant shared about her grandfather's immigration to Pakistan did not make it into either of the readings of the data. The story did not matter in configuration with the theories or research questions or methods, yet in my responsibility to her it mattered dearly.

noticeable and allowed me to see what was taken for granted in each reading. In **Chapter 5**, I elaborate on this process.

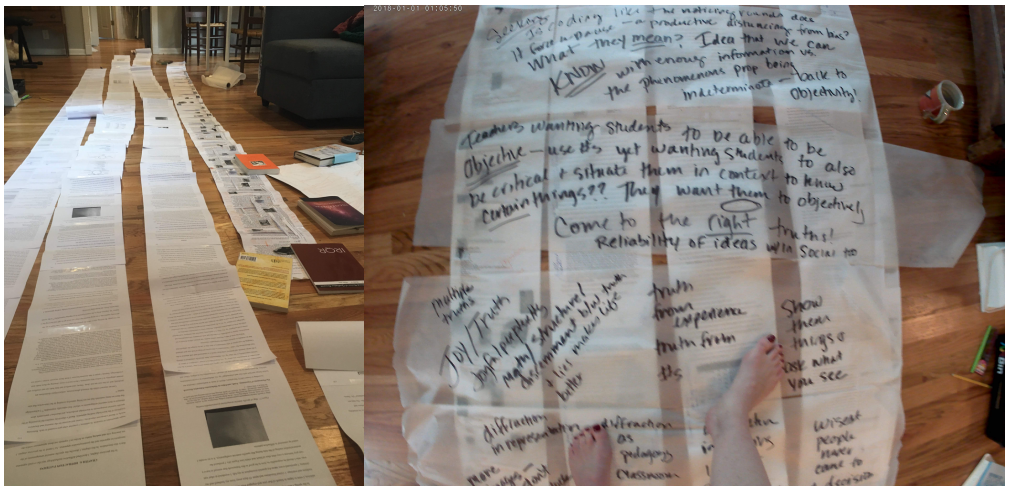

Figure 6. Diffractive analysis, April 2019.

This writing was brought into stillness by deadlines and page limits and mostly deadlines. I have momentarily tied down these ideas for this writing, yet I hope the writing/reading creates movement in the field. This dissertation picks up and gathers bits and stones as it rolls along. Not everything will seem to fit, and I will not always draw the lines or make the connections that might be expected. This move is a deviation from the norms of dissertation, which are to demonstrate a competence and clear knowledge of a particular field with a direct line forward into the production of a coherent scholar.

In place of this clarity and directness, I offer the image that Donna Haraway (2016) provides of string figures (cat's cradle, for example) together with the image of the elementary

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How could something so important be excess to this research? In what configuration of theory, method, data might it have mattered? I have included this story in Appendix F, knowing that this placement enacts a cut that regulates this story as outside the bounds of what can count as mathematics education research.

school gym class gathered around the edge of a parachute (see Figure 7), that I hope that you will think with as you read. Both the string and the parachute seem to have definite dimensions and material make up. They can be seen and touched and measured. Their shape is determined by the movement and pressure of many points, and the shapes that are created at times prompt joy and surprise. Sometimes the parachute falls flat unexpectedly, and the string will get tangled and knotted. Hopefully, there is some joy along the way.

Figure 7. Parachute configuration/reconfiguration.
See https://ccaschool.com/elementary-wellness/

CHAPTER 1: THE GASP, FIELDS, AND LIMINALITIES

I am of the field,
of girl,
of woman,
of wife…,
of daughter.
I am in the field,
of education,
of English,
of architecture,
of mathematics…,
of qualitative research,
There was a girl,
of the trees,
of the rock,
of the sky,
of the field,
And the field was of her.
And them.
And sometimes she felt,
at home,
and mostly,
not.

Mostly she tried to be
good.
Mostly she was tired of trying to fit.
The rows too confining.
The fences too tall.
The chemicals used to keep the field productive,
too harsh.

Is there a
not-field?
A space undefined,
unfenced,
untreated,
natural,
sprawling,
wild?

She knows it does not exist.
Can't exist.
And, she wonders,
can she carve out this place?

What might it look like to throw open the gates,
do they swing easily?
Is there a groove in the ground from their frequent opening?
Who can pass?
Who has the key?
What might come?
Come what may.

The Gasp, Breaking the Interval in the Liminal

The space between the aisles at the poster session was tight, less than four feet across with posters on both sides, bodies had to turn, shoulders angled to navigate; and it was long—at least a sixty-foot tunnel of cardboard and nerves. My co-presenter and I had to press against the table to make room for the bodies to move through. The woman walked past our poster, then her face turned; she must have caught a glimpse of it out of the corner of her eye. She gasped, a response to stimuli, unfamiliar, out of place, frightening? I laughed nervously and smiled. She asked, "Did your kid do that and you brought it anyway?" There were scribbly lines all over the poster, so her response made sense. Was what we had done just nonsense? Kids' play? The poster had registered to her within a portion of a second as out of line, unorderly and insensible. Our poster certainly did not follow the pattern clearly established and followed by the other forty posters in our aisle. Block title at the top, university emblem, research question, methods, data, graph, analysis, findings, discussion, and most importantly clear statements as to what was now known because of the research. Our poster was messy, with text broaching boundaries and lines squiggling across it and poetry on one edge (see Figure 8). It was decidedly not in line. We were refusing convention and were disciplined with a gasp. The woman was provoked though and excited in a space of rationality and order. A space of composure. The woman and I spoke for a moment, and then she moved on. The image on the poster, that prompted that gasp, has continued with me. I made it then, to signal to the messiness of research, the illusion of clean and linear representations of data and methods. Now, I think it with liminality and fields.

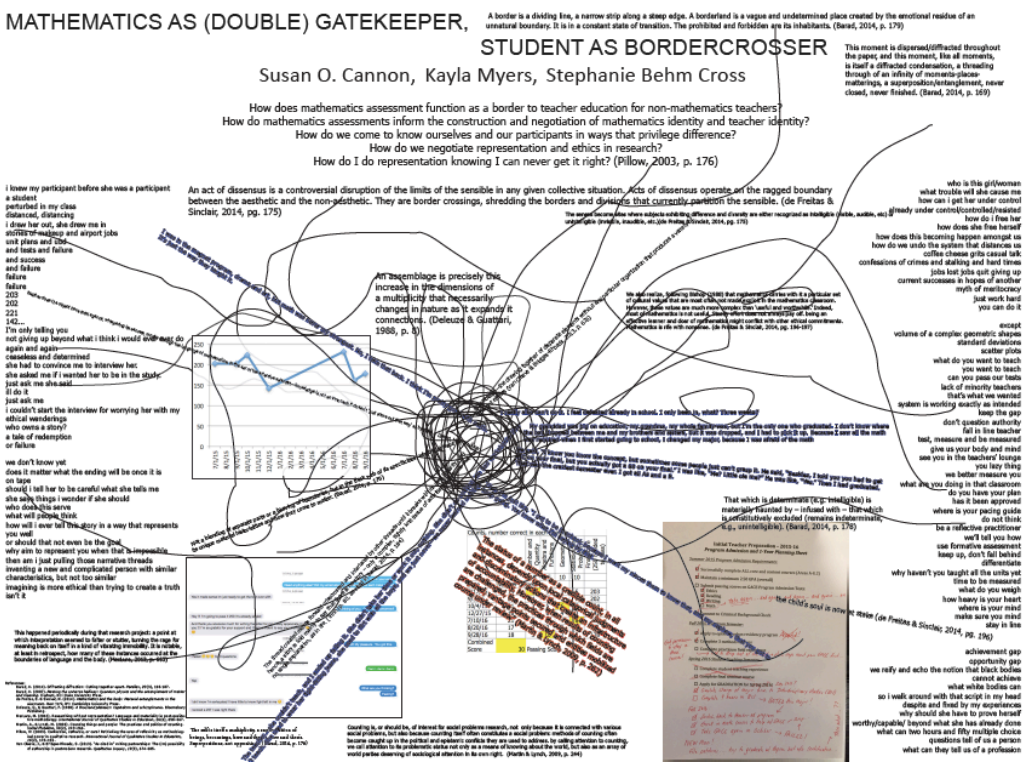

Figure 8. Poster from mathematics education conference in 2016.

In entering the field of mathematics education research, I have been nudged explicitly and implicitly to affirm certain ways of being and doing that are designed to help me fit into the field. I am attuned to the sensible and the legitimate, and I reach around for the borders and the boundaries that define my field. The gasp showed me a boundary. I had already seen it when we raised our poster amongst the rest, but the gasp signaled it again (see Figure 9). A couple of other people stopped who were interested in our work and familiar with some of the scholars that we cited: our poster was not that out of line to them. They had been straying from the field as well. There was a small opening, a boundary becoming blurred and fuzzy.

Intra-action, Diffraction, and Making Kin

I struggled from the beginning of my doctoral research to figure out to which field I belonged and how to *be* in the field. I have come to believe that there is no right field for me to be in. Instead, I will twist field, fold field, and *unfield* by making connections across fields. As I

traverse fields, I make marks and marks are made on me. Both field and I are disrupted. The boundaries of field are called into question as I move across them carrying the marks of other fields. I argue that this disruption of boundaries matters for more nuanced and responsible relations within and across fields. Each disruption produces a liminality within which values are renegotiated. The production of liminalities is important in the academy because it works against easy sorting and categorization and slows down the neoliberal research machine. If lines are not clear and boundaries are blurred, responsiveness to the particulars of the material arrangements is required. Inventive research methods and new concepts or theories can produce liminalities that demand relational rather than prescribed becomings for researchers, fields, materials, and texts.

The concepts of intra-action (Barad, 2007), diffraction (Barad, 2007; Haraway, 1992) and making kin (Haraway, 2016) are particularly productive for thinking about how academic subjects and fields are produced. Diffraction and making kin are creative and inventive practices that provoke intra-actions that produce liminalities within and between fields. Barad (2007) proposes intra-action in contrast to interaction to acknowledge that all the participants in a phenomenon are mutually constituted and entangled with one another and are not cleanly divided. Participants can include objects, texts, humans, and more-than-humans. I use the term *participant* to signal the liveliness and involvement of everything within the intra-action. In phenomenon, agency is distributed and the binaries of nature, culture; active, passive; and human, material are flattened. Intra-action prompts me to think fields as in process and inclusive.

In addition to intra-action, I think fields with diffraction (Barad, 2007; Haraway, 1992). Diffraction allows for a non-hierarchical methodology through which different texts, theories, and thoughts can be placed against one another so that they are dialogically read to engender creative and unexpected outcomes. Diffraction requires interest in the details of the arrangements and acknowledges and respects the contextual and theoretical differences between readings. The

hope is to provoke new thoughts and theories toward inclusion and responsible action. Diffraction is meant to disrupt linear and fixed causalities and to work toward interference patterns that mark difference for its effects so that we can see how differences matter.

I advocate for a horizontal depth, a moving across fields-in-process as productive for seeing differences across fields and for making kin (Haraway, 2016). Haraway suggests that we "make kin in lines of inventive connection as a practice of learning to live and die well with each

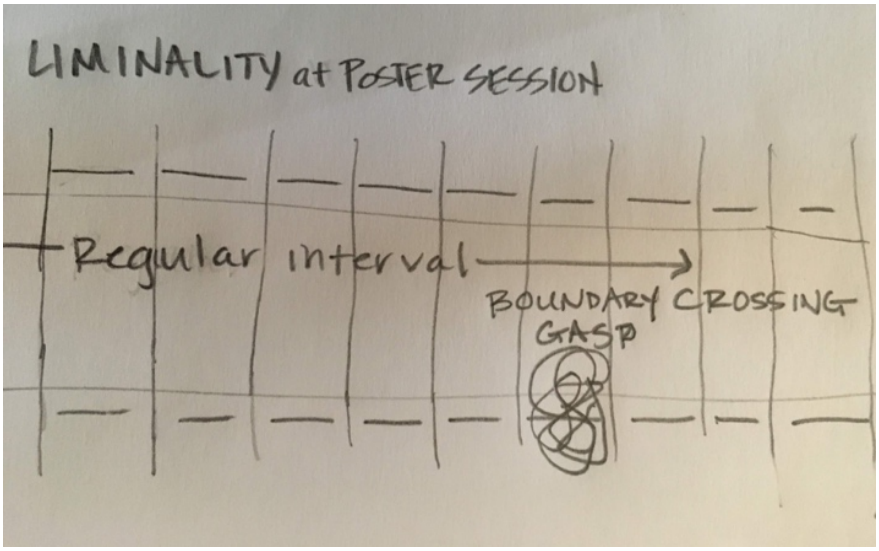

Figure 9. Interval of poster session and the gasp of boundary crossing.

other" (p. 1). Diffraction affirms links between seemingly opposite schools of thought, it is one way of making kin. I momentarily *unfield* myself so that I am permitted to move across fields widely and invent connections that stitch together a liminal space, the broad folded and intricate expanse of between. In liminalities, words and things do not fall into easy categories and the work is to keep it complex and uncertain, not pulled too much to one side or the other, or the other. Without interval, the gasp would never come because all would be irregular.

Field Production and Maintenance

In format and content, this chapter works to put field into liminalities, to blur its meaning in a productive series of iterations so that field refuses stability. Wide travels and lines of

connection in the liminal spaces between fields can pull fields into closeness and make what seems distant into kin. Pulling threads across fields allows for a diffractive reading so that we can see how differences across fields come to matter (see Figure 10). I examine connections between fields, and Davies, Flemmen, Gannon, Laws, and Watson (2002) explain—

> look for and work with the lines of fault, the forking and rupture of knowledges that are already in play.… and to extend our knowledge of how speaking- and writing-as-usual create and sustain cultures of practice that we wish to move beyond. (p. 31)

Davies and colleagues gesture toward work that digs into and upturns the taken for granted to create difference.

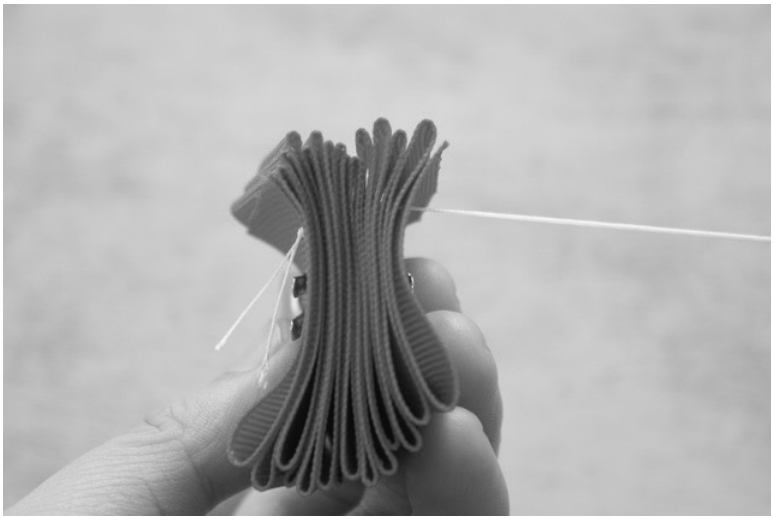

Figure 10. Threads pulling fields into closeness.

This chapter's format is an experiment in diffractive writing and reading (Cannon, in press; Hepler, Cannon, Hartnett, & Holbrook, 2019; Holbrook & Cannon, 2018). In academic writing, clear and concise narratives are encouraged and theories or ideas that distract from the main paper are burnished off to care for the reader. This caring means that scholarly writing most often stays *in field* in terms of citations, format, and content. I disrupt this notion and deterritorialize academic becoming with a proliferation of field figurations as footnotes—drawing on St. Pierre's (1997a) conception of figuration as something that produces "a most

rigorous confusion as it jettisons clarity in favor of the unintelligible" and "enable[s] us to move toward realities in different ways" (p. 281). The footnotes come into intra-action with the more legitimate academic text of the main paper to continuously trouble the notion of field as a stable backdrop to research. As I describe the format of this chapter, I am furthering the cut between what counts as scholarly writing and what is regulated to the margins, yet this move is necessary to maintain a care for the reader who expects a linear argument that flows and directly states its point. The field figurations are optional invitations to disrupt the linearity of the text. The resulting unexpected intra-actions allow alternate radical possibilities.

When Does a Field Become a Field?

Building on Barad's (2007) intra-action, de Freitas and Sinclair (2014) propose inclusive materialism in *Mathematics and the Body: Material Entanglements in the Classroom*. They propose that the intra-action of theories and research could allow for the radical reconfiguration of school mathematics. de Freitas and Sinclair begin their text with the question, "When does a body become a body?" They do not directly answer the question, instead leaving it purposefully open to "trouble assumptions" (p. 16). Beginning with this question seems a useful tactic when considering academic fields. The question, as de Freitas and Sinclair explain, "directs our attention to the processes by which bodies—be they human or non-human—come to be counted as bodies, processes whereby a body is recognized as a body" (p. 16). Of course, they cannot, and neither can I, account for all the processes or ways that a body/field[14] is recognized, but they read and write body diffractively through many different theorists. In doing so, the taken for

[14] Field Figuration/Extensions of Body/Field**:** de Freitas and Sinclair (2014) provide an example of a blind man with a stick and assert that the stick becomes an extension of the body, in assemblage with it. I wonder about the manuscript published in a cross disciplinary journal as a cane that reaches out in assemblage with researcher to allow her/him/them to feel and know differently and somehow beyond—and I immediately question beyond…what is the ripple effect of tapping *into* another field? What can be felt from a distance?

granted boundaries of body are troubled. In this section, I take up some of de Freitas and Sinclair's questions and assertions about bodies and use them to think about academic fields[15] and when they become. What are the processes whereby a field is recognized as a field[16] and comes to be counted as a field?

de Freitas and Sinclair (2014) consider the body "less an entity and more a process of becoming" and ask, "might it make sense to think of the body as a growing and contracting assemblage of diverse materials?" (p. 16). They draw on complexity and systems theorists' conception of the body as "an ecological system sustained through boundary negotiations" (p. 17). de Freitas and Sinclair point to the difficulty in addressing the complexity of the multiple scales of interaction of bodies and the "way these different spatial and temporal scales are interwoven" (p. 22). These descriptions are useful in considering academic fields, as they imply the multiple factors that come into play in field[17] production. The field is not a single entity. It is a part of a material-discursive system with which researchers intra-act.

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[15] Field Figuration/Field as Bramble**:** The field is overgrown hasn't been plowed in decades, there are no machine ruts, only sprawling growth, tendrils reaching to light and to soil, searching for sustenance and finding it. The berries that erupt are accessible only to birds who approach from above or to critters who scurry beneath for fallen fruit. Perhaps, on the periphery a visitor to this field might pluck some ripe fruit, but to come further in would require the loss of blood. "Qualitative inquiry, then is a web of associate practices, a confederation, at times almost a bramble bush of research endeavors, each related in some ways but not in other ways to alternative endeavors" (Preissle, 2006, p. 688).

[16] Field Figuration/Making the Field**:** "*When* was the field? I strayed far from 'official' data, overwhelmed with a lifetime of the real. So, I made the field as I wrote. I *laid out the field* in sentence after sentence in all the writing spaces I could find" (St. Pierre, 2018, p. 606).

[17] Field Figuration/Field as Undifferentiated: Most times, though I am already keenly aware that I am *in* mathematics education, I might not be aware of my intra-action in/with the field. Attending to our surroundings through quick categorization is neurotypical. For neurotypicals, "the crossing is likely to occur as if automatically… doorness disappears. The door figures as always-already passed through, habitually" (Manning & Massumi, 2014, p. 16). What if I saw more than fieldness or other than fieldness?

New academic fields emerge as an assemblage of scholars, journals, editors, conferences, materials, discourses, universities, technology, texts, handbooks, histories, stories, and on and on converge in a point of kinship or confluence. The influences on the creation of a field are complex and untraceable, yet powerful. Field production is a knowledge making practice and as Barad (2007) attests, "the point is not merely that knowledge practices have material consequences but that *practices of knowing are specific material engagements that participate in (re)configuring the world*" (p. 91; emphasis in original). Although there are many participants in fields, their arrangements matter. Academic fields reconfigure the world in assemblage.

As a part of their exploration of the body, de Freitas and Sinclair (2014) question *how* humans and materials participate to produce assemblages with agency. In their version of agency, de Freitas and Sinclair include the force of affect and the "potential energy of relations" (p. 24). They assert that the consideration of agency as relational and including human and non-human allows for a radical reconfiguration of the world that would not be possible if agency is centered in individuals. They posit body as assemblage and assert that in such assemblages there is no centralized control and no direct linear causation. Participants intra-act and things happen. In one of their examples, a girl practiced counting with an iPad. The assemblage includes the girl, the table, the iPad, the program, the instructor/researcher sitting nearby, the girl's utterances, the room, the previous uses of the iPad. The girl intra-acts in entanglement with the other participants in the phenomenon, she does not control it, the iPad does not control her, agency is distributed amongst all participants in the system, whether one would typically think of them as *active* or not. As researchers intra-act with academic fields, they are a part of a similar entanglement: researcher, Google Scholar, handbooks, advisor, college of education, elevator, dean, and on and on in entangled and mutual becoming.

When researchers look back and try to consider how fields have come to be (or from the example above; how the girl learned to count), they can attempt to trace a field's becoming by pointing to evidence of its existence, but they cannot account for all the participants in the intra-action or how each might have contributed given that actions cannot be separated out, but happen in intra-action. Yet, they look for and point to things that prove the fields have become. Kilpatrick (2014) asserts, "one measure of the maturation of the field[18] of mathematics education is that researchers have begun to study its history" (p. 271). Just as I might be able to point to the iPad, child, and researcher as an assemblage and consider that each came to matter in one child learning to count; scholars look back to trace the happenings in a field. Fields are substantiated through evidence in the field—the fruits of the field's labor (conferences, publications, handbooks, journals).

As scholars have asserted the emergence of their respective fields[19] (see, e.g., Gergen, Josselson, & Freeman, 2015; Kilpatrick, 2014; Preissle, 2006), they have inevitably cited the presence of new journals of their field,[20] handbooks (or chapters in handbooks), conferences (or special interest groups at conferences), textbooks, and the number of publications deemed to be *in the field.* For example, Adler, Ball, Krainer, Lin, and Novotna (2005) argued for the

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[18] Field Figuration/Field Defined: an open land area free of woods and buildings.

[19] Field Figuration/Field in Flux: Small hands grip the edges, thick and rough. Boundaries stitched and reinforced to protect the thinner cloth at the interior. Hands rise and fall. They move somewhat in unison, yet always one somewhat follows the other, the timing shifts and the shape morphs in response as tension builds and subsides at each point along the edge. No one is in the middle, and we all make the middle….

[20] Field Figuration/Field Crying Out: "The field is already expressing a tendency toward something singling-out. Even now, in the immediacy of the moment, something is already calling out for the right to stand out efficaciously or poetically" (Manning & Massumi, 2014, p. 14). How can we attend to the field and the not field? How do we categorize and generalize a little less quickly or with more curiosity to see what is there rather than to sort?

emergence of mathematics teacher education [MTE] as a field[21] pointing out the "increased attention to MTE in recently published international handbooks in the field" (p. 362). Handbooks are powerful in establishing and shifting the borders of fields.[22] Simons, Olssen, and Peters (2009) contended it is "through the vehicle of a handbook, [that] the field[23] of study strengthens its disciplinary borders" (p. ix), writes its history, and conditions the possibility for its future by making space for exploration, introducing new scholars, or reifying prominent names in the field.

What are the Borders of the Body/Field[24]?

Handbooks are just one example of disciplining materials that intra-act with fields/researchers. Field[25]-scholar-text assemblages are mutually entangled in their becoming. When a field becomes discernable and legitimate depends on the knowledge that it produces and how that knowledge is taken up and dispersed. Conventional wisdom tells us that a scholar

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[21] Field Figuration/Ripples in the Field**:** "Each subsequent conversation will relationally fold the thisness of conversing into its open field of emergence. A conversation never stands on its own, separate from its capacity to rejig the field of attunement. It has already spread like ripples on a fluid social surface" (Manning & Massumi, 2014, p. 119).

[22] Field Figuration/Dilating the Field: "Despret is not interested in thinking by discovering the stupidities of others, or by reducing the field of attention to prove a point. Her kind of thinking enlarges, even invents, the competencies of all the players, including herself, such that the domain of ways of being and knowing dilates, expands, adds both ontological and epistemological possibilities, proposes and enacts what was not there before" (Haraway, 2016, p. 126–127).

[23] Field Figuration/Field Tendencies: "The field of immediate experience is not composed of objects. The flower is the relational conduit for a field-wide tendency to expression. It might be called an objective rather than a fully bloomed object: a bud of an object. The field composes buds of objects as a function of its appellation for expression" (Manning & Massumi, 2014, p. 5).

[24] Field Figuration/Between Fields: What might it mean to be between. Betweenness implies two. Two somethings. Perhaps all is middle—as Deleuze and Guattari would assert. I feel the betweenness or at least the boundary. I feel that I am on it, in it? In the boundary, is that possible if betweenness is not?

[25] Field Figuration/Keeping up with the Field: "A researcher who myopically persists in studying one narrow topic for too long may fail to keep up with the field" (Confrey, 2017, p. 3).

cannot become legitimate or recognizable without a field[26] to which they are aligned or to which they are placed within, to be sensible, they are disciplined into the boundaries of the field. This disciplining goes beyond what might be thought of in a humanist tradition as the boundaries of person as academic and into all aspects of their life. Colebrook (2017) describes the power of knowledge practices whereby, "discipline is achieved by a series of practices that study and manage life, and this management is not so much normative as *normalizing*" (p. 653). Becoming academic is not separable from the rest of one's life. It is entangled. The field[27]-scholar-text-mother-partner-girl-athlete-patient-and on and on become together pulling and pushing in turn toward some shifting yet agreed upon normal. Thus, the ethics of field maintenance and border control and field figuration is an ethics of relational becoming. The gasp is not predetermined or intentional. It comes in relation with posters/bodies/carpet/texts/discourse. The gasp is possible because of a particular material arrangement, and it makes other becomings possible.

Considering field/scholar/text entanglements distributes agency across bodies, but it does not remove responsibility. If anything, considering these entanglements makes response-ability more crucial and complex. If a researcher's actions in the field matter in both their own and the field's mutual becoming then they must consider how particular intra-actions might create space or open up, and others harden boundaries and close down. If difference is seen as unsettling, and causes a gasp, and a field[28] is desiring stability and respectability, then the borders harden toward difference. If, however, difference is taken up as opportunity to notice *effects* that differences

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[26] Field Figuration/Enjoying Between: Being in the space between fields leads to a complexity and resonance both of which are enjoyable. They push; there is joy/challenge at the edge and between where things are less stable—being in between or on the edge is exhilarating, thrilling…and dangerous.

[27] Field Figuration/Field Defined**:** an area of cleared enclosed land used for cultivation or pasture.

[28] Field Figuration/Field Defined: land containing a natural resource.

might allow rather than point to or critique difference, borders might open up. Diffraction affirms difference as relational. What happens when we engage with _____? What happens when we think with _____? Barad (2007) explains, "boundary production between disciplines is itself a material-discursive practice" and asks, "how do these practices matter and for whom?" (p. 90). Each boundary researchers enact is a cut in the field.[29] It separates the outside and hardens the inside. It is a cut where researcher and field are "(be)coming together-apart" (Barad, 2012, p. 208). Researchers make boundaries in fields that in turn make them in an ongoing co-production that simultaneously brings them together and makes divisions.

As researchers, we make these cuts and ruts in the field. In reviewing manuscripts or conference presentations, we approve or deny entry to the field, and our bodies are also marked by these cuts. Boundaries are hardened or loosened. These cuts matter. The boundaries of the field are indeterminate and change in assemblages with other materials. They shift through complex intra-actions. de Freitas and Sinclair (2014) promote "deessentializing" the body with a focus on "difference over identity in the quivering unstable assemblages that constitute bodies" (p. 34) in their processes of becoming. What might happen if we think of the field as quivering and work to deessentialize it? Could deessentializing allow for more or different lines of "inventive connection" (Haraway, 2016)?

The field/scholar/text is quivering with potential. Possibilities are numerous but are not completely open. Differences make fields and differences within fields pull at the borders of the

[29] Field Figuration/Becoming the Field: "The autistic becomes the field, integrally co-compositional with it. For the neurotypical, the field comes already saturated with affordances the field proposes, with openings or object-buds offering themselves as conduits for the field's coming expression, already oriented efficaciously. This efficacious tendency in neurotypicals lends the field more 'naturally' to the kind of cross-checking that is for fact-finding rather than for story-making in a poetic sense" (Manning & Massumi, 2014, p. 11).

field[30] creating intensities in its becoming. As scholars within a field are disciplined toward the norms of the field, there are always disagreements about what constitutes normal or legitimate scholarship. Each piece of writing or conversation or body carried into a particular space and how it is received in that space matters for how the field[31] continues to become. As I described in the introduction to this chapter, when I brought a different version of poster, another scholar in the field[32] gasped. I had gone too far out of the field,[33] I stretched the boundaries until they broke, and I was not seen as legitimate, a boundary crossing marked by the gasp of another scholar. Confrey (2017) asks, "what makes a piece of research worthy of recognition, citation or application?" (p. 3). This question is particularly lively in mathematics education research as mathematics educators consider the frontiers of the field (Stinson & Walshaw, 2017). As Palmer, Simmons, and Hall (2013) point out the "claiming and creation of boundaries are fundamental in distinguishing subject areas" (p. 496). There is a comfort in stable borders and expectations that allow for streamlined knowledge production. Uncertainty gnaws at the borders of fields and slows down the knowledge economy. There are reasons for the reduction of uncertainty, and yet liminalities are differently productive.

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[30] Field Figuration/Field Defined: the place where a battle is fought.

[31] Field Figuration/Field Defined: large unbroken expanse (as of ice).

[32] Field Figuration/Exchange Across Fields: "What is at stake is less the equivalence between objects exchanged than the sustenance of their relational field of exchange*ability* within certain qualitative parameters.…Uncrossed, the limit is a sustaining factor in the serial production of new iterations of events in the same qualitative field" (Manning & Massumi, 2014, p. 124–125).

[33] Field Figuration/Field Defined: an area or division of an activity, subject, or profession

Intra-action Across/Between Fields, Field Liminalities

When fields[34] come into intra-action or scholars write or think across fields the borders of scholar/field/text entanglements stretch and shift. Greckhamer, Koro-Ljungberg, Cilesiz, and Hayes (2008) point out, "the permeability of the disciplinary boundaries varies across scientific fields or disciplines" (p. 311). In some fields, "the forces of tradition are strong" (Gergen et al., 2015, p. 7) and stretching borders seems nearly impossible, while in other fields[35] questioning of borders is anticipated. Inter-action among particular fields can lead to an increase or decrease in the speed of change, openings, or calcifications. Gergen and colleagues (2015) contest that the intersection of the field[36] of qualitative inquiry with psychology allowed the field of psychology to shift in ways that would not have been possible in another assemblage. They explain, "although university policies and disciplinary gatekeeping have tended to balkanize the social sciences, the qualitative movement creates fresh and significant openings for the flow of ideas and practices across the discipline" (p. 7). The *effect* of the difference in ways of thinking that qualitative inquiry allowed was to open the field[37] to new ways of knowing.

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[34] Field Figuration/Field Defined: the sphere of practical operation outside a base (such as a laboratory, office, or factory), geologists working in the *field*.

[35] Field Figuration/Fields in Intra-action: "Waves, on the other hand, and not things per se; rather, they are disturbances (which cannot be localized to a point) that propagate in a medium (like water) or as oscillating fields…. Unlike particles, waves can overlap at the same point in space. When this happens, their amplitudes combine to form a composite waveform.…the resultant wave can be larger or smaller than the individual component wave" (Barad, 2007, p. 76).

[36] Field Figuration/Fields of Emergent Relation. "When the capitalist economy subsumes all other economies, it is not just capturing monetary value. It is capturing processes of individuation. It is capturing entire fields of emergent relation. It is capturing powers of becoming" (Manning & Massumi, 2014, p. 121–122).

[37] Field Figuration/Fields of Paradigms or as Paradigms: "Producing 'good' research means following the prescribed methods and methodologies of data production, analysis, and publication. How might the notions of 'good' change as a field if we embraced paradigming?" (Kuby & Christ, 2017, p. 8)

Scholars from senior to emerging discipline themselves toward their conception of the field[38] and what they think will make sense within it, and they are disciplined to create and perhaps stay in the field[39] as they are pointed to particular scholars or citations to take up in their development as scholar. We, as researchers, create the field,[40] we work the ground, we discipline ourselves and the field.[41] This creating is an ethical matter; it is reconfiguration—each publication and how we write it and where we submit it matters. Certainty, although it allows smooth production, creates fields with hard borders that become unquestionable. In maintaining some uncertainty or curiosity about what belongs in a certain field[42] or what terms within fields are set and have fixed meanings, we can then unthink hardened thoughts and open back up. Scholar, university, department, handbooks, journals, citations, rankings, are all entangled in a research machine, a field producing machine where counts and efficiency matters:

> Workers, machines, managers, are entangled phenomena, relational beings, that share more than the air around them; they help constitute one another (e.g., in some cases

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[38] Field Figuration/Field Defined: a region of embryonic tissue capable of a particular type of differentiation, a morphogenetic *field.*

[39] Field Figuration/Exceeding the Line: "No line can be drawn around spectral data—the territorial assemblage always exceeds any line which seeks to contain it" (Nordstrom, 2013, p. 338).

[40] Field Figuration/Absence of Field.

In a field
I am the absence
of field.
–Mark Strand, 1980

See https://www.poetryfoundation.org/poems/47541/keeping-things-whole.

[41] Field Figuration/Field Defined: a set of mathematical elements that is subject to two binary operations the second of which is distributive relative to the first and that constitutes a commutative.

[42] Field Figuration/Field Defined**:** the individuals that make up all or part of the participants in a contest. The election attracted a large *field* of candidates.

> machines and workers help domesticate each other, in other cases they help each other run wild). (Barad, 2007, p. 239)

It seems that in most academic fields, researchers work toward domestication—how might we help each other run wild?

Straying from the Field/ Marks on Bodies[43]

Academic fields are made through our intra-actions with(in) them. As researchers test the borders and stray outside the perceived lines, the field is reconfigured, and new tracts are laid that might be followed. Straying then is an important action to consider as we participate in fields' becomings. I have always been between disciplines, in the liminal spaces between fields. Straying for some is a way of being, not a considered action to take. Ahmed (2006) explains,

> I was "brought up" between disciplines and I have never quite felt comfortable in the homes they provide.… Disciplines also have lines in the sense that they have a specific "take" on the world, a way of ordering time and space through the very decisions about what counts as within the discipline. Such lines mark out the edges of disciplinary homes, which also mark out those who are "out of line." (p. 22)

As researchers find themselves "out of line" they might ask what the effect of that misalignment is, what are they responding to or with, what connections are being made that matter? Greckhamer and colleagues (2008) suggest that scholars who do not take up "legitimate" theories with in their fields invite rejection and isolation. Further they caution, "legitimate theories cannot be interdisciplinary because theories, in the current academic disciplinary system, are legitimized only within their respective disciplines" (p. 318). Adler and Lerman (2003) described the field[44] of mathematics education's resistance to research questions that did not center on mathematical activity. Questions that were perceived as outside mathematics were

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[43] Field Figuration/Field Defined**:** a series of drain tiles and an absorption area for septic-tank outflow

[44] Field Figuration/Field Defined**:** a particular area (as of a record in a database) in which the same type of information is regularly recorded

not seen as of value because “they are not (fully) legitimate disciplinary questions” (Greckhamer et al., 2008, p. 319).

Just as some questions are not legitimate, so too are particular methods or ways of knowing deemed as illegitimate within fields. Although bridging these borders is possible, it is argued that only “the most senior members of a discipline can afford to do so” (Greckhamer et al., 2008, p. 319). Yet, senior members of disciplines are often so firmly implanted in the field that this type of work becomes almost unthinkable.

Becoming with Liminality/Possibility

The materialisms that Barad (2007) and de Freitas and Sinclair (2014) take up imply and allow, even insist, that our actions in/with the world impact its/our becoming (see Figure 11); therefore, we have ethical response-ability to that becoming. For me, this lies between hope and despair. It is an accounting of the impact of my presence and a humbling that I cannot control anything independently. So, I must admit that each action I take matters and is outside my direct control.

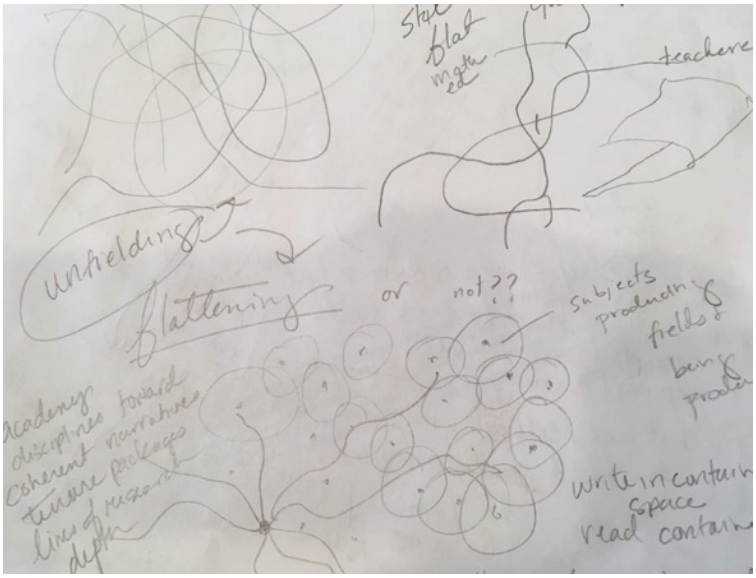

Figure 11. Conceptions and organizations for field intra-actions.

Possibilities for the field[45] are generated in a mutual becoming. Research can be what de Freitas and Sinclair (2014) refer to as "speculative and creative work" that "pushes the field into new uncharted terrain and allows for new conjectures about teaching and learning" (p. x). Each manuscript we write, or book we read, or call we write, or abstract we construct, or story we tell a neighbor about the kind of work we do, matters in the field's and our becoming. Haraway (2016) says it this way—

> it matters what matters we use to think other matters with; it matters what stories we tell to tell other stories with; it matters what knots knot knots, what thoughts think thoughts, what descriptions describe descriptions, what ties tie ties. It matters what stories make worlds, what worlds make stories. (p. 12)

If we can bring fields into closeness and make connections in the liminal, we can see points of beauty in difference. It is a reciprocity like the ones that Kimmerer (2013) describes: "its wisdom is that the beauty of one is illuminated by the radiance of the other" (p. 47). Kimmerer asks us to think two (at least) types of knowledge together and to see beauty in the pairing and importantly to create something in response.

When educational researchers make connections across fields and are responsive, we create a liminal. Barad (2013) explains: "what keeps theories alive and lively is being responsible and responsive to the world's patternings and murmurings. Doing theory requires being open to the world's aliveness, allowing oneself to be lured by curiosity, surprise, and wonder" (p. 207). When we are firmly in field, we cannot hear the murmurings as invitations for invention, all we can do is gasp at difference. And perhaps the gasp produces a liminality—a space for doubt and eventually an opening, however slight.

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[45] Field Figuration/Knowable Space: Prior to the trip, before we embark, we flip through the guide. What are the spaces and places that have been traveled before, what places are safe for us to enter and what should we expect to find there? Only with this knowledge, do we dare enter the field.

The Not-Field of Qualitative Inquiry

Judith Preissle (2006), in her commentary on qualitative inquiry, asserts that qualitative inquiry is not a field or a discipline:

> Qualitative inquirers do not agree on who we are, what our purposes might be, and much less on whether we have boundaries and what those boundaries might be (Howe, 2001). We are a messy, contentious bunch who come from a variety of disciplinary and subject-matter backgrounds. (p. 686)

She further asserts that this non-agreement is productive. It keeps qualitative inquiry supple and in movement. Perhaps, researchers should not aspire for their fields to become too mature, so that they are hardened off from creative and innovative practices. Preissle argues that qualitative inquiry is not a field[46] because it continuously questions its identity. Can consistent questioning of our borders, make any group of researchers "the not-discipline, not-field, but maybe community of practice" (p. 686) that Preissle describes? What would it take for Greckhamer and colleagues (2008) *postdisciplinarity* to undo fields[47] and hierarchies? Could qualitative inquiry be a *not* field, a community of practice, without other disciplines and fields within which to practice?

Colebrook's (2017) investigation of education and philosophy implies that making connections between a field and a practice that is open can lead to productive de-disciplining and unfielding. She advocates "tying education to philosophy, where the latter is not a discipline (in the sense of a specific terrain of know-how or expertise) but a *not knowing*" (p. 652; emphasis in

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[46] Field Figuration/Before the Field: "These gestures, while tuned to the words, perform a kind of alternate rhythm, opening the conversation to its pre-articulation—the ways in which it moves beyond the said in to the register of the felt but unsaid" (Manning & Massumi, 2014, p. 118).

[47] Field Figuration/Gravity Field: "Gravity is a field, after all, not simply a directionality. The potential of the field cannot be understood apart from what it does, from what it can do, in relation to the fieldings it co-activates. Attending to the more-than is a way of saying that the field itself is attentive to its potential shifts, that the field has within its potential the capacity to create conditions for difference" (Manning, 2016b, p. 119).

original). In a discipline that is trending toward standardized knowledge production, the insertion of practices such as philosophical thinking that provide space for not knowing, is crucial to allow questions of value that are hard to measure. Being responsible in intra-action is an ongoing and moving ethical call that cannot be predetermined. Philosophy and qualitative inquiry produce liminalities, blurring boundaries in fields and between disciplines that might otherwise harden their boundaries toward efficient production of knowledge.

Not knowing leads to blurred boundaries between fields and inventive connections across fields[48] (see Figure 12). This work is not about destroying fields[49] but about noticing and questioning the taken for granted and bringing fields[50] into closeness and then expanding them back out to see what difference it makes.

[48] Field Figuration/Field Defined: the space on the surface of a coin, medal, or seal that does not contain the design.

[49] Field Figuration/Field Defined: the area visible through the lens of an optical instrument.

[50] Field Figuration/Entering the Field: I read a story—I can't remember when or how or why I read it. A girl told of being in the back of her family car and having been finally given the responsibility for opening the gate out of her driveway. She described her careful planning to make sure that her entry and exit to the car were smooth and efficient and that she moved the chain just so, so that her father would not get frustrated with her awkwardness or slowness. It seemed that perhaps the point was for her not to do anything that would get noticed as being different or out of synch or questionable. Do it like your older sister or brother. Fit in, be like us. She got back in the car and the father did not say anything. This silence was exactly what she wanted, to have done the job well in a kind of routinized way. To fit in and not incite anger or frustration or even attention. When I read the story, I felt kind of sad at all the times that I unconsciously, or very consciously, do that work, staying quiet, pleasing the authority figure, not making too much noise, not making anyone wait or think or notice or be disturbed.

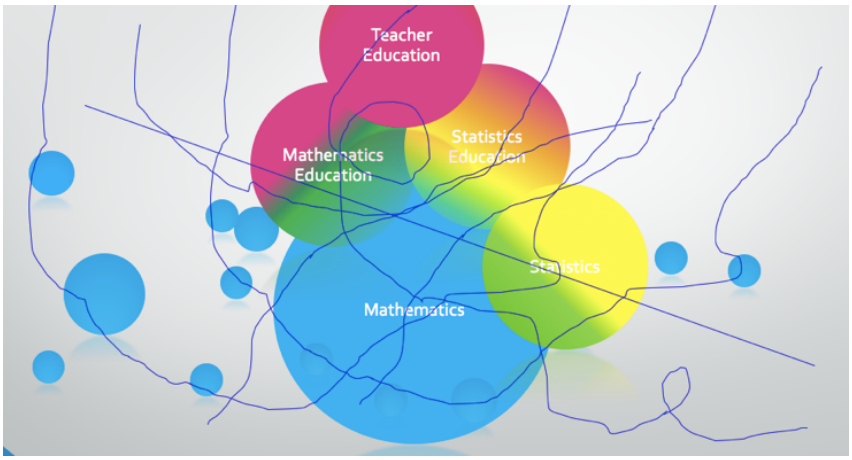

Figure 12. Inventive lines of connection across fields.

de Freitas, Lerman, and Parks (2017) assert that qualitative research "performs an important political role by increasing awareness of alternative practices, as well as pointing to inventive and unscripted futures for mathematics education" (p. 177). Unscripted futures are produced in and through liminalities not within hardened categories. Qualitative inquiry attends to things of value that cannot be easily measured or counted. It disrupts easy categorization even as it refers to the structures in fields.[51] The marks and traces of the field remain and provide the interval by which the effects of difference are noted. Whether with the concepts I have proposed or with tools others have suggested—figurations (St. Pierre, 1997a), concept as method (Lenz Taguchi & St. Pierre, 2017), thinking with theory (Jackson & Mazzei, 2012)—as educational researchers, we need to continue to unfield, and seek spaces of *not* knowing, and to do it with responsibility. We are reconfiguring the world as we work in and between the field and across fields. There might be gasping involved. Hopefully, as qualitative inquirers in neoliberal times,

[51] Field Figuration/Coming Undone in the Field: I lie on my back reading; I slide over every 15 minutes or so to stay on the border of sun/shade, to be perfectly warmed. I smile, and underline, and laugh out loud as I read. I roll over onto my belly and kick my legs. I think about how he said he always could find me by looking for my legs up in the air. I smile and cry and read some more.

venturing into the liminal produces possibility to learn through lines of connection and relationality, how to live and die together well (Haraway, 2016). Living and dying together well is not about smooth lines of production and easy categorization. It is about being willing to be in and produce the liminal and to wonder at its strange beauty.

Interlude

how often i am told where i can go
and when i can be there
and what i can see there
and what that site is for
this is the place for research
this is the place
for exercise
this is the place for sleep
this is the time for exploring
this is the time for
11:31, 29 minutes to be someplace else
what will i be by then. where will i have become
what is taking me there, mind, body, thought, soul, spirit, discourse
have i made any choices today or am i following the citation trail
constituted by my readings i have seen
what i was expected to see
written what was expected to be written
nothing new
everything new
everything old
all traces
across field[52]

[52] I was given some feedback to explain this poem. I remembered something that I had written about poetry and searched my files and found it. The paper was dated December 7, 2015:

> To represent myself, I resort to poetry. There, it is always a failure and always truth. Multiplicity lives there, of interpretations, of meanings. To represent others, I have been taught to re-sort, categorize, construct from scraps; piecing together bits of data, bumping them against each other, perhaps a contradiction or a complement. I wonder. I freeze, incompetent, "a point at which interpretation seemed to falter or stutter, turning the rage for meaning back on itself in a kind of vibrating immobility" (MacLure, 2013a, p. 663).

I wrote this then and stand by it now. I resist explaining the poem, because it sits in a liminal. It's brevity and incompleteness and uncertainty are what are attractive to me. It provokes wonder of some sort even if the wonder is only about what is missing. Going back to that paper I found other poems that I had written then, that I am afraid will be lost if I do not bring them into this dissertation. They are a remnant of the specific material arrangements of my academic

Research Questions

I open my dissertation with this discussion of fields because I want to recognize that as I write this dissertation, I am becoming with it. We co-constitute one another. In this constituting, moves are made to cross fields, blur boundaries, and invent connections. As a result, liminalities are produced, and cuts are enacted. This production is informed by humanist, poststructural, and posthumanist theories, [53] and was co-constituted through my engagement with an initial study in a middle school classroom, my review of statistics and mathematics education literature, and the methodological tensions and snags I encountered in conducting and writing up the initial and ongoing study.

In order to think this dissertation as on going and in intra-action, I take up Karen Barad's (2007) apparatus to see how the way researchers take up data matters. I propose her diffractive methodology as a way to consider the effects of differences in knowledge making practices. Within this methodology, I arranged knowledge making apparatuses with the data from the original classroom study in purposeful entanglements (Marn & Wolgemuth, 2016) with theories. I produced iterations of the data in at two versions (humanist/interpretivist and poststructural). Then, I diffract (Haraway, 1997; Barad, 2014) those readings to consider questions about how data function and are constituted in research methodology and statistics education. The overarching research questions that framed this study were:

becoming. I think I will find homes for them here and see what they do. They had been cordoned out of this academic writing, this production of legitimacy.

[53] This discrete listing implies a cleaner division in the versions than I think is possible. I expect that the eventual three versions will have traces of all three paradigms: interpretivist, poststructuralist, and posthumanist. Furthermore, I acknowledge that neither the concepts or philosophers identified as interpretivist, poststructuralist, or posthumanist are cleanly distinguished from one another, so they are always already entangled.

1. How are data produced through the interaction of participants, site, context, theoretical framework, materials, methods and processes?
2. How are data productive of different knowledges/ways of thinking/questions in various entanglements and configurations?
3. How might multiplicity in method and theory open up potentials for different views of knowledge and truth, validity and responsibility?

Purpose and Significance

The overarching purpose of my dissertation is two-fold, first I consider specific aspects of data and statistical literacy in one middle grades mathematics course. I was curious about how the data that students engaged with around controversial issues in the media might shift their thinking about those events. In addition, I was interested in the practices and pedagogy the teachers of the course used to engage students in the topics and in dispositions of statistical thinking as outlined by Wild and Pfannkuch (1999). The study contributes to the fields of mathematics and statistics education as it explores how middle school students and teachers used data and statistics to consider controversial issues in the media, tracing the data to a model of statistical thinking. The teacher practices and student work that are highlighted inform practice in middle grades classrooms and brings questions forward for consideration by the field about how dispositions of statistical thinking can be developed in middle grades classrooms.

Secondly, I argue for the importance of theory and qualitative inquiry in mathematics education research. I show that poststructural theories have already opened up important spaces in the field of mathematics education research. I imagine theory and qualitative inquiry in mathematics education as paths across and through fields, some worn, some yet to be trampled. Theory and qualitative inquiry allow crossings that might not otherwise be possible, and they open space and make cracks in hardened places in fields where new or different ideas can seep

through. I claim that taking up different theories provokes new questions that require new methods and types of data to be considered. Different theories and ways of knowing allow different ways of doing science and different views on what counts as data in knowledge production.

CHAPTER 2: FIELD INTERFERENCE

Imagine two stones dropped into a pond. The first stone creates a field of movement and response within the water and waves move out from the place of connection between water and stone. The second stone also creates movements that vary depending on how it hit the water and the specificity of the stone's shape and size. Two fields are created in the water in response to the entry of the stones and those fields then come into intra-action (see Figure 13). The waves intersect and build speed or perhaps slow in relation. Again, the pattern that is created is dependent on the specific material arrangement of stones and water and force and angle. A fascinating potential for creation and difference emerges with the intra-action of fields.

Figure 13. Wave/field intra-action.

In this chapter, I outline the fields of literature with which I am intra-acting and draw attention to some of the movements within and across them. I am interested in how the continued inter-action and thinking across fields might open up space for students to be mathematician differently. It is important to me that in this dissertation, I continue to come back to how this work might matter for students, schools, and teachers. In working across fields and considering the taken-for-granted structures within fields, I aim to continue the work of opening up space in mathematics classrooms for students previously unrecognizable as mathematician.

As I stated in the previous chapter, I do not suggest that educational research would benefit from the removal of structures within fields or that that removal is even possible. Instead, I suggest that moving across and between fields makes the ever present and sometimes unnoticed structures more visible. I aim to attach to those structures and patterns and use the tensions between structures in fields to build a string figure that others might take up and reconfigure (see Figure 14). I do not intend for this figure to be static, and it cannot be as the fields and structures all shift in intra-action.

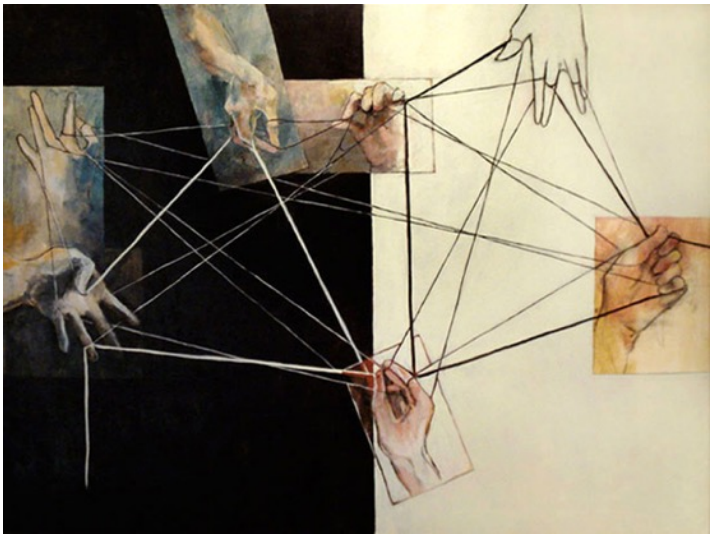

Figure 14. Baila Goldenthal in *Cat's Cradle/String Theory*, 2008.

As a move to care for the reader, I tentatively map the following section, so that she/he/they has a sense of the figuration that awaits. First, I argue that statistics education research is a particularly fertile field to make connections and produce tensions both at the university level and at the classroom level. Second, I trouble and explore the boundaries between mathematics and statistics and mathematics education and statistics education. Third, I trace how theory and qualitative research methods have worked tensions in mathematics education research and how mathematics education researchers have called for more attention to theory in the field.

There, I revisit Karen Barad's (2007) intra-action and agential realism and de Freitas and Sinclair (2014) inclusive materialism.

The Gasp in Statistics Education Research

At a campus visit to a large university in the southeast, I described my research project during a 45-minute presentation to the faculty of a combined mathematics and science education department within a college of education. I argued for statistics education and the inclusion of statistical thinking and dispositions in middle grades mathematics classrooms. I discussed some of the main points from the previous chapter and described my intentional working and thinking across fields. I was clear that I saw great value in crossing boundaries. As I closed the presentation and invited questions from the faculty, an audience member asked why I thought statistics should be included in the mathematics curriculum. She asserted that it should be in science or social studies curriculums and classrooms, not a burden for mathematics teachers. A debate ensued across the room between mathematics and science education faculty.

Each side had a perspective on whether statistics should be included in their field. It was clear in the discussion that statistics education was not considered a field in its own right. This incident confirmed the disciplining and fielding that is continually occurring in academia (cf. Chapter 1). It also assured me that statistics education is an important and fertile field within which to position my study. Like the gasp at the mathematics education conference, this argument is a gesture of the territorialization of what does and does not count as mathematics and what should be included in the mathematics curriculum. The way these boundaries are enacted matters for students.

In the discussion with the faculty, someone asked why I thought statistics should be taught in mathematics classrooms. I, probably without enough forethought, replied that I saw it as a "gateway drug to mathematics" for students. In my experiences teaching middle school, I

had seen many students enter 8th grade with fixed notions about who they were as mathematicians and what counts as doing mathematics. While in their literacy and social studies classes they were regularly encouraged to debate and discuss ideas, my students did not expect to do that in their mathematics classes. I found students clamored for hints and advice or fixed procedures to get to *the* right answer. They were not used to a tolerance for uncertainty in mathematics classrooms, for wondering how a problem might be done or what other ways it could be approached.

Over the years, in response to this resistance to expressing uncertainty in mathematics, I looked for ways to make space for my students to be uncertain in my classroom. As an example, I structured a 12-week unit of my 8th grade class around modeling. I tied the science and math curriculum for which I was responsible to modeling. I found this valuable because it drew attention to the models that students had been using in mathematics classrooms for years without thinking of them in those ways. I had an idea that if students could see that they were creators in mathematics classrooms and that those creations involved choices and therefore there was variability in what could be deemed as a right response depending on the context, then students who did not otherwise see themselves as mathematicians might find a place.

In my anecdotal experiences, I saw students think differently about what they were being asked to do in math class. For example, when I talked with the students about bivariate data, we talked about the relationships between the variables and how that relationship might be represented, about graphs as models of a relationship between two variables. It was not procedural, I did not give students a table and a series of points to graph on a fixed and pre-scaled coordinate plane. Instead, I might give them a data set with a context and then ask them to model the relationship between the two variables. They might choose to show the relationship with a table, or an equation, or a graph. Each graph could be different depending on the scales

chosen for the axis and how it was labeled and colored. These may seem like simple distinctions, but they matter for how the reader understands the relationship. Then as a class we would consider how each model (table, equation, graph, etc.) worked in representing the relationship. What had to be abstracted in the model? What attributes did each represent more accurately? What misconceptions might someone have about the relationship because of how it was modeled?

In this work, there was a tolerance and expectation of uncertainty and multiple options from students and from me as the teacher. It is these options for uncertainty in mathematics classrooms that I am interested in pursuing. In this chapter, I consider potential openings within mathematics education research for uncertainty. I do this in two spaces. First, I consider the field of mathematics education research and how statistical thinking in elementary and middle school classrooms prompts students to "deal with" variability and consider its implications. This highlighting of variability requires working with messy data, uncertainty. Second, I consider the field of mathematics education research and map how theory and qualitative research methods have been used in mathematics education research to open up spaces for mathematics to be thought differently.

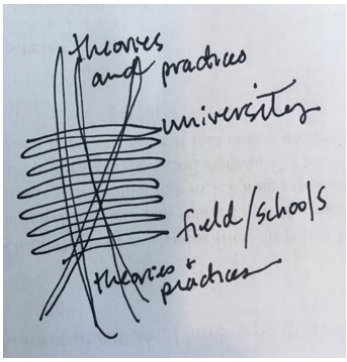

Figure 15. Theory practice in intra-action with schools and university.

The goal of both of these reviews is to not just see what space there is in the research fields but to consider how and why this research might matter for students and schools (see

Figure 15). I do not abide by the theory practice divide that the things that happen in universities and dissertations are distinct from the field of schools. Traditionally, researchers have conceptualized the university as the place to explore theory and the schools as the place to try out practices that are drawn from those theories. The work "on the ground" in schools is practical and the work in universities is theoretical. I suggest, like others before me, that we work the ground in universities and schools to consider how the theoretical/practical and political/ethical moves that we make across spaces matter for students in schools. As I hope Figure 15 indicates, these theories and practices cut across and move through schools and universities.

Border Production: Statistics *or*/*and* Mathematics?

Statistics is defined by the omnipresence of variability. Although in many mathematics classes that I have observed in over almost 20 years as an educator and another 20 as a student tend to produce regularity and conformity—neat rows of students[54] with neat and orderly lines of equations where students clearly show their work in a clean trajectory. Statistics is open to messiness, it relies on it. In this work, I want to create a string figure that makes inventive lines of connection between the variability and uncertainty inherent in statistics (and sometimes in statistics education) and consider how those threads can be pulled into mathematics education.

Statistics and probability standards have had a presence internationally for the past 25 years and have had a significant presence in the United States since 1989 with the National Council of Teachers of Mathematics (NCTM) publication *Curriculum and Evaluation Standards*

[54] At the Association of Mathematics Teacher Educators (AMTE) annual conference this year (2019), which I just returned from, a second-year teacher presented with a university professor. He discussed his principal's resistance to the arrangement of his room in groups rather than rows, especially for his Algebra classes which were comprised of mainly African American students. He stated that the principal did not mind that he did group work with the geometry students, primarily White children in this school. The specific material arrangement of the classroom mattered for how the administrator thought particular bodies were allowed to participate in mathematics.

for School Mathematics. In the almost thirty years since, there have been calls for increased attention to statistics education, especially given the current political climate and increased access to data (Engel, 2017; Wild, Pfannkuch, Regan, & Parsonage, 2017). But as my opening vignette points out, not everyone has been happy about the inclusion of statistics in mathematics curricula. The field of mathematics education is relatively young and has been working to establish itself as legitimate in ongoing relation with the disciplines of mathematics and psychology (Kilpatrick, 2008). Even the field of mathematics education emerged from mathematics, yet is not considered its own discipline, a field of statistics education has more recently emerged from statistics.

Statisticians and mathematicians distinguish themselves with disciplinary boundaries that have refrains in statistics education and mathematics education. Yet, the boundaries between the fields are not hard or clear. Within the development of the fields there have been boundary negotiations amongst statisticians, mathematicians, and mathematics and statistics educators. Standards related to statistics topics have been placed in the mathematics curriculum and are prevalent in the recent NCTM publication *Catalyzing Change for High School Mathematics Classrooms*[55] (NCTM, 2018) that includes four focus areas in statistics and probability and 17 essential concepts, more than Algebra and Functions (10) and Geometry and Measurement (12) or Number (2). At the most recent AMTE conference, I attended two sessions that focused on the distinction between mathematics and statistics (Burrill & Franklin, 2019; Conner, Peters, & Gomez, 2019). In these sessions, a difference in the ways statisticians and mathematicians was emphasized, inductive for statistics and deductive for mathematics. In addition, statistics was

[55] It is of note that this document lists the following as the purposes for high school mathematics: "Expand professional opportunities, Understand and critique the world, Experience the joy, wonder, and beauty of mathematics" (NCTM, 2018, p. 9).

recognized as depending on variability and messiness and mathematics was described as working to make clean and transparent structures. In neither session were the differences taken as absolute. Though these negotiations continue, the call for action on the topic of statistical literacy for K–12 students is clear.

Movements in the Field of Statistics Education Research

Statistics educators stress the importance of beginning statistics education early as the complex thinking involved takes years to develop (Shaughnessy, 2007); therefore, the field of statistics education has expanded internationally and new journals and conferences have surfaced to address issues relevant to teaching statistics to students prior to college (Biehler, Frischemeier, Reading, & Shaughnessy, 2018).

Although statistics has been part of the K–12 curriculum now for almost thirty years in the United States, performance on national measures, such as National Assessment of Educational Progress (NAEP) have shown that although there have been gains that there is still work to be done in developing students' statistical thinking. Jones, Langrall, and Mooney (2007) studied the 2003 NAEP results and found that although over half of the eighth-grade students considered the potential for bias in data, less than half recognized the potential for bias in the sampling methods or drawing inferences from small samples. They also noted that—

> Performance was poor on complex items that involved interpretation or application of information in tables and graphs. There have been little to no gains from 2000–2003, and performance on such items may in fact be slightly eroding. (p. 960)

Due to the evidence from student performance on standardized assessments and qualitative research in statistics classrooms around teacher knowledge (Jones et al., 2007; Shaughnessy, 2007) and the clear need for statistical literacy in society today, statistics educators are calling for increased and different attention to statistics in schools. To see change in middle grades and

secondary schools, English (2014) argues that statistics education should begin in the earliest years of schooling as it takes time to develop the complex thinking involved.

Calls for increased attention in statistical literacy are centered in a few major concerns. One is the increase in the scope, types, and quantity of data that are being collected and put to use by the media, businesses, and politicians. Second, there is a concern for the types of thinking that is required in order to process and consider decisions in this type of data rich environment. Third, there is a concern for the ways that a lack of statistical literacy is connected to issues of equity in public and personal realms.

Carver and colleagues (2016) *Guidelines for Assessment and Instruction in Statistics Education* (GAISE) report states that the "rapid increase in available data has made the field of statistics more salient" (p. 4). Engel (2017) speaks directly to the impact of the media and the "massive amounts of data…that are increasingly accessible" (p. 45), stating—

> it is ever more important for citizens to be critical consumers of media reports, being aware of the misuse of statistics and knowing effective ways to overcome them…to develop the capacity to make sense of the staggering amount of information collected in our increasingly data-centered world. (p. 48)

Not only is the amount of data a concern but also a critical eye toward how data are created and "Why, for what purpose, and in whose interest, was the data collected in the first place?" (p. 48). The data deluge as some call it creates the need for statistical literacy, but there is still debate about how to develop that literacy (see, e.g., Gal, 2004; Garfield, Le, Zieffler, & Ben-Zvi, 2015; Langrall, Makar, Nilsson, & Shaughnessy, 2017; Lesser, 2007; Merriman, 2006; Watson & Callingham, 2003). Most recently, Weiland (2017) has proposed the integration of critical literacy practices and statistical literacy to inform a critical statistical literacy that asks students to take on divisive and controversial issues using the tools of statistics and critical literacy.

As increased attention is given to teaching students statistics at a young age, researchers are interested in the statistical thinking of teachers and students and models for assessing that thinking (Burgess, 2009; Jones et al., 2007; Valentine & White, 2006). This call to teach students statistics is not focused solely on the acquisition of statistical definitions and procedures but rather is tied to students' ability to participate in the world. Biehler and colleagues (2018) recently emphasized, "to achieve informed participation in public decision processes, it is inevitably vital for concerned citizens to be statistically literate" (p. 185). The definition of statistically literate adults and students has been developing along with the field and several models have been designed to evaluate and define the important aspects of statistical thinking. English and Watson (2017) state concisely the heart of the call for more attention to this area:

> Statistical literacy is increasingly important in today's society where data inform nearly all aspects of our lives. An ability to deal intelligently with such data is essential for a fulfilling and productive life. (p. 1)

Statistical literacy as it is defined in curricula involves at minimum basic skills in understanding statistical information such as organizing data and constructing data tables and graphs in various forms. However, statistical literacy as it is conceptualized by leading researchers goes beyond the application of procedures and the construction of tables and graphs. The key to statistical literacy versus a simple knowledge of statistics is the incorporation of statistical concepts and tools in the consideration of important questions within a particular context.

Gal (2004) describes statistical literacy as a person's ability to "interpret and critically evaluate" statistical information and arguments and to "discuss or communicate their reactions" (p. 49) to the information. Watson (2006) describes statistical literacy as—

> the meeting point of the data and chance curriculum and the everyday world, where encounters involve unrehearsed contexts and spontaneous decision-making based on the ability to apply statistical tools, general contextual knowledge, and critical literacy skills. (p. 11)

Key in this definition, and building on Gal's, is the attention to new contexts and application through decision-making.

Engel's (2017) definition of statistical literacy also acknowledges the context and the complexity of social phenomena and "the ability to explore, understand, and reason about complex multivariate data" (p. 45) within those contexts. In Engel's view, statistical literacy in society today requires the operationalization of variables and definitions of concepts involved in the statistical question or investigation. Engel advocates the use of "authentic" data explorations to develop statistical literacy as "real data about society are often more complex and messy" (p. 46). It is this messiness that necessitates higher order thinking and questioning from students and teachers alike.

In 1993, Katherine Wallman, then President of the American Statistical Association, gave an address on the topic of statistical literacy. She defined statistical literacy as—

> the ability to understand and critically evaluate statistical results that permeate our daily lives—coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions (as cited in Watson & Callingham, 2003, p. 2).

Wallman brought forward an aspect of statistical literacy that has just as much relevance almost thirty years later, the implications for our public and private lives. In both public and private realms, statistical literacy had been associated with concerns about equity. In considering both the public and the private uses and misuses of statistics, O'Neil (2016) has made the argument that statistics can be and are being used to further widen gaps in society. Watson and Callingham (2003) describe it as follows:

> Statistical literacy is not only important to our society as a whole; it is also relevant to the individual members of society as they make decisions in their personal lives based on information and risk analysis provided by others in the community. Decisions related to where to live, what type of employment to seek, whether to gamble, or what car to buy may be influenced by data provided from outside of one's individual experience. (p. 2)

All of these definitions point to the importance of statistical literacy to how students are able participate in their lives and the material conditions of the lives they are then able to make. Statistics education cannot be conceived of as the straightforward ability to perform statistical tests or to organize and graph predetermined data. If educators intend to position students from all backgrounds to be able to participate intelligently in important decisions about their personal lives and political and public participation that affects them all, students need to begin developing dispositions for statistical thinking early and work with real, messy data.

Researchers have been considering how best to conceptualize, teach, and assess statistical thinking. Jones and colleagues (2007) pointed to a basic curiosity, awareness, and imagination that would allow students to be "open to alternative interpretations and seek deeper meaning" (p. 964). Additionally, they point to the need for students to then be able to "critically read and evaluate information…and to adopt a healthy questioning attitude toward what is presented by sellers and buyers, by scientists and by the government, by politicians, and by the news media" (p. 964). Furthermore, Engel (2017) suggested that for students to be active citizens they will need to "fact-check on their own" with "a disposition to engage with evidence" (p. 47). In the update to the original GAISE report (i.e., Franklin et al., 2007), the authors stand by the original six recommendations to statistics and mathematics educators:

1. Teach statistical thinking.
2. Focus on conceptual understanding.
3. Integrate real data with a context and a purpose.
4. Foster active learning.
5. Use technology to explore concepts and analyze data.
6. Use assessments to improve and evaluate student learning.

(Carver et al., 2016, p. 6)

Carver and colleagues (2016) then added two new recommendations that are related to statistical literacy. The first recommends an investigative process be used so that students do not leave statistics courses with the "mistaken impression that statistics consists of an unrelated

collection of formulas and methods" but rather see statistics as fundamental to "making sound decisions" (p. 6). In the second recommendation, the authors consider (as the researchers previously cited), the complexity of the world and encouraged giving students experience with multivariable thinking to answer "challenging questions that require them to investigate and explore relationships among many variables" (p. 6). Statistical literacy is important for all students and citizens to be able to consider decisions in the personal and public realm; however, it is especially important for marginalized populations. Konod and Higgins (2003) state, "no skill is more important to acquire in the battle for equity than statistical literacy" (p. 193).

Bakker and Derry (2011) point to the lack of coherence in statistics education due in part to its location across fields. They call for change from the theoretical foundations of the field and consider the ways that knowledge is conceived within statistics. They point to three current challenges in statistics education and suggest that educators "avoid inert knowledge" or knowledge that can be reproduced but not put to use effectively; "avoid atomistic approaches found in many textbooks to foster coherence form a student perspective" and suggest that curriculums aim for coherence rather than a particular "sequencing" (p. 6–7). This fundamental challenge to the epistemic foundations of statistics relates to how statistics educators enact statistics in classrooms. Bakker and Derry state, "To speak of a knowledge domain such as statistics is not to refer to anything fixed but rather to a field within which concepts are connected to each other by virtue of the uses made of them" (p. 24). If we expect students to develop complex understandings of statistics, then they have to be given opportunities to make connections between concepts and meaningful contexts flexibly. In addition, this perspective suggests that mathematics educators and statistics educators should think about the use of their disciplines across fields and contexts.

As was shown through the definitions of statistical literacy, attention to the context is crucial in the field. This attention to context is not the way that statistics education is currently being enacted in most schools. Engel (2017) states, "cleaning, transforming, and structuring data are necessary skills, but these skills are not taught in the traditional classroom with its focus on inference-based statistics problems with tidy data" (p. 46). This concern relates to Bakker and Derry's (2011) point that statistics education cannot be made clean and tidy and still be useful to students in their lives.

The sequencing of statistics topics and straightforward processes of statistics investigations, such as the step by step problem solving process,[56] are the focus of national standards and recommendations, yet these standards do not always include "sufficient detail on the importance of reasoning about data" (Biehler et al., 2018, p.185). Biehler and colleagues report that the research continues to show that students tend to focus on surface features of the data and should be provided with opportunities to do more "substantial interpretation" (p. 185). To get to these more complex interpretations, students have to have different opportunities to interact with statistics in the classroom.

The field and content of statistics education provides one avenue for opening up and disrupting mathematics classrooms that could allow for radical reconfiguration. In the remainder of this review, I consider the current climate of mathematics education research and the fertile places for invention and reconfiguration within this field. There is a present and palpable opening, I argue, in the mathematics education research community for radical reconfiguration.

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[56] Wild and Pfannkuch (1999) presented two cyclical processes to be used in statistical thinking, one interrogative (generate, seek, interpret, describe, judge), one investigative (problem, plan, data, analysis, conclusions). Details of these cycles are provided in Chapter 4. The original GAISE report (i.e., Franklin et al., 2007) recommends a framework that breaks out four steps: formulate a question, collect data, analyze data, and interpret results.

Refielding Mathematics Education Research

At the opening plenary of North American Chapter of the International Group for the Psychology of Mathematics Education (PME-NA), Rochelle Gutiérrez (2017) suggested that the mathematics education research community needs to "think not only about more ethical ways of applying mathematics in teaching and learning but to question the very nature of mathematics, who does it, and how we are affected" (p. 2). She proposed that "interaction between different knowledges, different ways of knowing and different knowers" (p. 2) could serve to respond to and perhaps address the precarious state of our planet and our relationship with it. Gutiérrez is not the first leader in the field of mathematics education research to call on the community to consider mathematics education research differently. Tate (1995) called on the community to consider policy in relation to equity in mathematics education. He commented that he found the "paradigmatic boundaries of mathematics education somewhat narrow," and he intentionally modeled his work after scholars who "crossed the epistemological boundaries of their fields to provide a more cogent analysis of important issues facing African Americans" (pp. 425–426).

D. B. Martin, Gholson, and Leonard (2010) responded to two significant events that concerned the boundaries of the field of mathematics education and what counts as mathematics education research. The first was the March 2010 editorial in the *Journal of Research in Mathematics Education* (*JRME*) that called on readers to look for the *mathematics* in mathematics education research. Heid (2010) reminded readers that *JRME* publishes mathematics education research articles in which the "math is an essential component rather than being a backdrop for another area of inquiry" (p. 103). This editorial was a disciplining move that regulated concerns about equity, race, research methods, or theory within mathematics education that did not focus on mathematical concepts, outside the acceptable boundaries for mathematics research. In that same year, NCTM sponsored a session at its researcher's

conference entitled *Keeping the Mathematics in Mathematics Education Research* (Teppo, Speiser, Søndergaard, van den Heuvel-Panhuizen, 2004); D. B. Martin and colleagues (2010) later convincingly argued both events "marginalize[d] scholarship within particular areas of focus" (p. 13). D. B. Martin and colleagues did not claim that mathematics is not important; instead, they called on the community to continue "efforts to add needed complexity to the understanding of learners, their social realities, and the forces affecting these realities" (p. 15). In particular, they pointed to the lack of progress in the area of equity despite rigorous empirical research for underserved populations. This lack of progress seemed to, in their words, "demand that we pursue *all* promising areas of inquiry informing us about how to help them experience mathematics in ways that allow them to change the conditions of their lives… now is not the time for restricting the production of knowledge" (p. 17). Notably, D. B. Martin and colleagues and Gutiérrez (2017) recognize and point to the way that our conceptions of knowledge determine the conditions of our lives.

The NCTM has directed attention to issues of equity through policy particularly with the *Principles to Actions: Ensuring Mathematical Success for All* (NCTM, 2014) document. Although it was a public proclamation of the organization's commitment to equity, D. B. Martin (2015) responded to the mathematics education community calling for a revolution of values, a new way of thinking, and a radical decolonizing of education for the collective Black:

> The hard truth is that the outcomes and inequities lamented over in *Principles to Actions* and previous documents are precisely the outcomes that our educational system is designed to produce. Equity oriented slogans, statements about idealized outcomes, and tweaks to teaching or curricular practices within this system do not change this fact. (p. 21)

In his response to D. B. Martin and the NCTM community, NCTM president Matt Larson acknowledged that "significant structural obstacles, including tracking and teacher assignments that disadvantage students who have been marginalized, remain unacceptable practices in too

many schools" (2016, para 3). But as D. B. Martin (2015) pointed out, although it seems that the larger mathematics education community is beginning to recognize these structures and obstacles the call for more equitable practices has been met with intense standardization and an increase in measurement and assessment of students and teachers in the last few decades (see, e.g., Attick & Boyles, 2016; Biesta, 2015). These solutions attend to a positivist, linear, cause-and-effect pathway for producing change in mathematics. In contrast to making measured improvements to the current regime of mathematics, Elizabeth de Freitas and Natalie Sinclair (2014) and Rochelle Gutiérrez (2017) promote more equitable spaces and configurations for doing mathematics through a radical reconfiguring.

In the following sections, I consider research in mathematics education that has already crossed epistemological boundaries and worked to open up spaces for mathematics educators, teachers, and students to think themselves, mathematics, and schools differently. I then explore Barad's (2007) construct of intra-action and the potential possibilities it offers for qualitative methodology, specifically in mathematics education. Finally, I come back to calls by Gutiérrez (2017), de Freitas and Sinclair (2014), and D. B. Martin (2015) to consider how possibilities for ethical action are structured by the ways we do and think research, thus offering new possibilities for ethical action by doing and thinking research in new or different ways.

Movements in the Field of Mathematics Education Research

Recent research in mathematics education is considering how theories can open up ways to think differently. de Freitas and Walshaw (2016) describe their approach to theory as impacting their thinking and meaning-making, explaining that "the act of defining or creating new concepts is precisely what theory has the potential to do. Thus, theory is a creative tool, an inventive approach to making meaning, as well as being an intervention into current cultural practices" (p. 4). In this frame, theory becomes not just something that a researcher thinks about

prior to research or something that is applied to research but an integral and inevitable component that impacts the meaning that is made through research. In their book, de Freitas and Walshaw put forward six theories and connect them with data as a way to consider the relationship between theory and data and research. They do not privilege a particular theory as better, stating, "there is no perfect incontestable theory" (de Freitas & Walshaw, 2016, p. 2); rather, they consider how each theory functions on the possibilities for how research and mathematics can be thought.

In concert with this text, David Stinson and Margaret Walshaw's (2017) chapter on theoretical frontiers in mathematics education research within the *Foundations* section of the NCTM *Compendium for Research in Mathematics Education* explains that theory has not always been considered a foundational aspect of mathematics education research. In the chapter, borrowing from Stinson and Bullock (2012, 2015), they summarize four moments in mathematics education: "(1) the process–product moment (beginning in the 1970s); (2) the interpretivist–constructivist moment (beginning in the 1980s); (3) the social-turn moment (beginning in the mid-1980s); and (4) the sociopolitical-turn moment (beginning in the 2000s)" and four paradigms: "prediction, understanding, emancipation, and deconstruction" (p. 132). They also describe how four theories: critical theory, poststructural theory, critical race theory, and feminist theory have entered the field of mathematics education and the potential for these theories to disrupt the status quo. It is their hope that these theories provoke readers of the compendium to consider how theory matters. Stinson and Walshaw state, "these 'new' traditions provide different ways to think and re-think the possibilities and impossibilities of mathematics education research" (p. 128). Inclusion of this chapter in the compendium is noteworthy as the handbook structures what is important in the field of mathematics education.

Poststructural theories have *functioned* to allow us to "move toward the unthought" (St. Pierre, 1997b, p. 185) in mathematics education, and to ask, what other important thoughts have we yet to think or unthink that matter in mathematics education? "How might we think possible worlds in which we might live differently? The test of his [Deleuze's] philosophy, then, isn't determined by judgment of true knowledge but by the kinds of lives it allows us to live" (St. Pierre, 2013, p. 225). Theories matter as they structure the way we do research and live our lives. In mathematics education, they matter because they structure mathematics curriculum, subjectivities, and classroom structures and interactions. In the next section, I consider how post theories have offered qualitative researchers in mathematics education different ways to conceptualize and enact their research.

Poststructuralism and Mathematics Education

Poststructuralism[57] has intersected with mathematics education for decades, and mathematics educators use of poststructural theories have made it possible to consider how meaning and knowledge get made and whose "interests are privileged, marginalized, or silenced"

[57] I use the term poststructuralism here and throughout this dissertation. Although the term postmodern is at times used interchangeably with poststructuralist and they connote similar ideas for many readers, there are differences in the ways the terms are used. These differences are not easily marked, especially because poststructuralism works against fixed meanings and signifiers. Preissle (2006), in discussing the history of qualitative inquiry and paradigms, consistently refers to "poststructural and postmodern" (p. 689) never listing one without the other. Skovsmose (2012) uses the term postmodern, "as a reference to a critique of Modernity" (p. 233) and its privileging of science, knowledge, progress, and education. Within the same article, Skovsmose, categorizes Foucault as postmodern although Foucault is in other spaces labeled a poststructuralist. It should be noted that the majority of philosophers/thinkers that are labeled as poststructuralist did not self-identify in that way and in fact rejected the label. Peters and Burbeles (2004) differentiate between postmodernism and poststructuralism explaining that poststructuralism take the place of the theoretical object structuralism, and postmodernism takes the place of the theoretical object modernism. Further, they advise, "when discussing postructuralism it is important to recognize it as a movement (perhaps construed in the musical sense of the term)—as a complex skein that intertwines many different strands and also conceals important differences among the thinkers identified as poststructuralist" (p. 30). This description, not definition, of poststructuralism is the one that I like to think with.

(Stinson & Walshaw, 2017, p. 148). Poststructuralism has been attributed to thinkers such as Derrida, Foucault, Deleuze and Guattari, Butler, and Irigaray. In general, poststructuralism refuses generalizations, questions the taken-for-granted assumptions of stable human subjects, the transparency of language and meaning, and the separation of human subjects as independent of discourses and social structures. Poststructural theories move from a conception of a student as an independent and stable subject to an evolving subject influenced by discourse and disciplining practices of societies. This move has changed the types of research questions that can be asked, allowing a different view of teachers and students as subjects that are constituted through interactions with the powerful discourses of school mathematics, education, and gender.

Valerie Walkerdine (1994) employed poststructural theory to question the taken-for-granted assumptions that were made in the production of the "appropriate" mathematical subject through developmental theories. Walkerdine argued that the theories of the development become truths produced the "desired kinds of subjects" (p. 65) as normal and pathologized difference. Walkerdine was particularly interested in the effects of gender and class on subject formation. She found that boys were more likely to be positioned as having potential, and girls were taken up as lazy or incapable. The gendered discourses around who could be bright in a mathematics classroom meant that girls were less likely to get called on and listened to. Walkerdine concluded, "this kind of thinking, to put it starkly, is destroying our planet and perpetuating domination and oppression. It is not a universal truth, the pinnacle of civilization, but an enormous and dangerous fantasy" (p. 74). She called attention to a prevalent discourse that was taken to be true, that boys are better than girls at mathematics. Conceiving of students with poststructural theories allowed her to consider how those discourses circulated and impacted teacher behaviors. It was not that individual teachers were sexist, rather, there was a truth about girls that needed to be unsettled that operated in the classroom and produced sexist discourses.

Building on Walkerdine's work, Mendick (2005) questioned why and how girls seemed to freely choose paths that reified their subjectivities. She found that girls were less likely to enroll in accelerated mathematics classes despite equal or higher achievement on mathematics assessments. She refused to position the girls in question as individual rational subjects who were deciding that they did not want to take accelerated math. Instead, she explored the discourses that were operating, namely, that math is legitimately powerful, and that gender is a natural binary. Once these assumptions were questioned, the association between boys and mathematics could be seen in reference to power dynamics in the classroom. Not only did using postructuralism as an overarching theoretical frame affect Mendick's conceptions of gender and mathematics but also it unsettled her research practices. Giving up the idea of the participant as a stable self-contained subject complicated the practice of interviewing and what could be produced from the interview. Instead of thinking of the interview as a benign activity to get truth from her participants, she considered the interview as a process that acted on her participants. Mendick considered how her participants' identities were formed through the interaction of the interview. This conception demanded an increased sense of responsibility between researcher and participant, a relational ethics.

Stinson (2013) deployed poststructural theories to consider the ways in which four successful African American male mathematics students negotiated the discourses surrounding the "White male math myth." In this study, poststructuralism allowed Stinson to not only think identity and the discursive practices in relation but also to rethink the way that he did research. Stinson conceptualized a research method that he did *with* participants rather than to or on them. Within a traditional research and theoretical paradigm, Stinson would have been regulated to keep an objective distance from his participants and not provoke or disturb their conceptions of their identity.

The researchers above considered the ways that subjects are produced in mathematics classrooms in relation to gender, mathematics, and race. Popkewitz (2004) and Llewellyn (2015) considered the discourses that make those subject productions in classrooms possible. Popkewitz drew attention to the inscription devices in the discipline of mathematics that "order and classify the objects of teaching" (p. 4). His work questioned the mathematics curriculum and how it holds up the assumption that knowledge is obtained in neat trajectories ready to be passed on to stable rational subjects. He questioned the production of knowledge in the mathematics classroom alongside research practices that structure the types of knowledge that can be produced. He called out his intent "to disturb and contest the objects of reflection and action, and to ask what orders truth and falsehood in pedagogy as a set of governing practices" (p. 28). Popkewitz used poststructural theory as a tool to question assumptions about what pedagogies produce.

Llewellyn (2015) considered three sites of production for the discourses that structure subject formations in mathematics' classrooms. She identified three main sites of production: research, policy, and classroom discourse. She explained mathematics education research as a site of production that relies on students as essentialized and stable with predictable trajectories for growth. She conceived of research as a particularly powerful site of production because it is taken for granted as authoritative and true. In the area of policy, Llewellyn theorized that students are produced by policy as individual measurable markers of society's progress, "like machines, pupils have to move at uniform and continuous rates." (p. 307). As the student is expected to move at particular rates, it is the teacher's responsibility to monitor that movement, in Llewellyn's words, "here, the responsibility for monitoring seems to be placed upon the teacher, with the pupils as a passive machine to be repaired" (p. 307). Llewellyn also explored student teacher talk as a site of production and considered how the documents and policies produce and structure teachers and students toward a step-wise, progress-oriented outlook on

education. Llewellyn found that the policies and research along with neoliberal currents in education have produced a view of students, teachers, and schools, as having predictable and regular progress toward established ways of being and knowing. Those that do not fit these trajectories are considered deviant and are consistently corrected.

Despite the work that poststructural and postmodern theorists have been doing in mathematics education to work against these stable trajectories, the machine of mathematics education needs additional disruption in order to work for marginalized populations. Margret Walshaw (2004) described the "postmodern analytical edge … invites a less certain space for research, pedagogy and practice" (p. 4). Thinking with poststructural theories has allowed mathematics educators to recognize and disrupt taken-for-granted assumptions that have been normalized and allowed them to think subjects, curriculum, and mathematics differently. Aside from the content of research, thinking with poststructural theory leaked into the methodology in these studies. Theory and practice like other binaries could not be cleanly separated and as mathematics educators began to think their research differently, they began to do and write about their research differently. The methodology was reconfigured through different ways of thinking and, in turn, doing.

Materialisms

Poststructuralism's "analytical edge" has already made particular cuts in mathematics education research. It has taken on the humanistic stable subject and the power of discursive formations; however, poststructuralism has been critiqued for its focus on the linguistic and lack of attention to the material. Although this focus may be more a function of how the theories have been taken up in educational research and not a lack of attention to materialism in the writings of Foucault, for example, who as Hekman (2010) asserts "wants to talk about the material parameters of that world and how materiality interacts with discourses" (p.63). Even so, new

materialism[58] was born out of this *lack* of attention to the material in poststructuralist and feminist writings. Educational research has entered the materialistic turn, where the question of what matter matters has been raised. New understandings and theorizations of quantum mechanics and environmental concerns have come together to produce theories that undo the nature–culture divide and decenter the human as privileged caretaker or dominator of the earth. New materialism has many spin offs and nomenclatures (speculative realism, object-oriented ontology). Dolphijn and van der Tuin (2012) explain that

> new materialism is fascinated by affect, force and movement as it travels in all directions. It searches not for the objectivity of things in themselves but for an objectivity of actualization and realization.... It is interested in speeds and slownesses, in how the event unfolds according to the in-between. (p. 113)

The key tenants of these new materialisms, like poststructuralism, function to trouble binaries and distinctive boundaries: "a loss of boundaries and certainty is fraught with much risk but also with the potential of producing new knowledge and new becoming selves" (Mazzei, 2013, p. 780). In addition, new materialist theories take seriously what matter matters and how it comes to matter.

Susan Hekman (2010) highlights Karen Barad's approach to matter as offering "a wholly new way to address questions of truth and knowledge" (p.72). Karen Barad, a feminist, philosopher and quantum physicist, introduced many useful and important figurations in the last two decades as she imagined her agential materialism into being. In this section, I focus on one of these figurations—intra-action.

Barad (2007) denies the existence of individual separate beings and objects through the exploration and study of Niels Bohr's "philosophy-physics" (p. 24). She is clear throughout *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*

[58] I use this term here as Heckman uses it; however, I also want to honor the critique of the new in new materialism that Tuck and McKenzie (2014) put forward.

that she is not "drawing analogies between particles and people, the micro and the macro, the scientific and the social, nature and culture; rather I am interested in understanding the epistemological and ontological issues that quantum physics forces us to confront" (p. 24). She refuses analogy in part because it implies a separateness that does not exist in her quantum inspired worldview. Nature and culture, for example, cannot be clearly delineated and separated. The term intra-action is born out of this recognition that things are not discrete but are always already entangled. Interaction implies separate entities that take individual action toward or away from each other. Instead, Barad considers intra-action that is always taking place between "two mutually entailed folds of the same realm" (de Freitas & Sinclair, 2014, p. 46).

In Barad's view, matter and meaning are co-constituted, inseparable, and becoming together. Just as matter and meaning cannot be separated, so too epistemology, ontology, and ethics cannot be thought apart. Researchers are "part of that nature that we wish to understand" (Barad, 2007, p. 26), we are becoming with when we research. Instead of separate objects, the smallest ontological unit in Barad's agential realism are phenomena, a unit of "nonessentialized reality" (Marn & Wolgemuth, 2016, p. 3). It is nonessentialized because even at the smallest unit it cannot be summed up and separated out as a single distinct entity with individual will.

Given that things are not thought of as separate and discrete, neither can they have individual agency, "rather what is understood as 'agency' in the relational materialist approach is a quality that emerges *in-between* different bodies involved in mutual engagements and relations" (Hultman & Lenz Taguchi, 2010, p. 530). In a research setting then, the idea of the researcher as an objective separate observer, who studies from afar to know a subject, no longer holds. Instead, researcher, students, teachers, materials are mutually entangled and constituted and come to know "from *a direct material engagement with the world*" (Barad, 2007, p.49).

In their mutual becoming, there is a distributed agency that structures possibilities, as Barad (2007) explains:

> Intra-actions always entail particular exclusions, and exclusions foreclose the possibility of determinism, providing the condition of an open future. But neither is anything and everything possible at any given moment. Indeed, intra-actions iteratively reconfigure what is possible and what is impossible—possibilities do not sit still. One way to mark this is to say that intra-actions are constraining but not determining….There is a vitality to the liveliness of the intra-activity, not in the sense of a new form of vitalism, but rather in a new sense of aliveness. The world's effervescence, its exuberant creativeness, can never be contained or suspended. Agency never ends: it can never "run out." (p. 177)

Agency cannot be housed in a particular object or assigned to a particular subject/object, and the possibilities and impossibilities cannot be predetermined but emerge in the intra-action, resulting in a bubbling up of possibilities. Although things are considered together and as inseparable: "entanglements are not unities. They do not erase differences; on the contrary, entanglings entail differentiatings, differentiatings entail entanglings. One move—*cutting together-apart*" (Barad, 2014, p. 176).

Barad's concept of intra-action and the overarching frame of agential realism demands a different conception of research. Heckman (2010) summarizes the principle advantages of agential realism, drawing on Barad. She claims that agential realism—

> grounds and situates knowledge claims in local experience […] privileges neither the material nor the cultural; rather, production is material/cultural […] entails the interrogation of boundaries and cultural reflexivity […] [and] underlines the necessity of an ethic of knowing; our constructed knowledge has real, material consequences. (p. 73)

In summary, agential realism "shifts the focus from the nature of representation to the nature of discursive practices" (Heckman, 2010, p. 74) and how they matter.

New Materialism in Mathematics Education

New materialisms and in particular Barad's agential realism are beginning to be taken up by mathematics educators and are effecting/affecting the types of knowledge that are being produced through research (see, e.g., Ferrara & Ferrari, 2017; Roth, 2017; Wolfe, 2017).

Elizabeth de Freitas and Nathalie Sinclair, scholars who bridge the fields of philosophy, mathematics, and feminism have taken up Barad's agential realism, among other theories, in their ambitious text *Mathematics and the Body: Material Entanglements in the Classroom* (2014). de Freitas and Sinclair (2014) pull the threads of various (and differing) theories, drawing on Barad, Deleuze, Rotmann, Ranciere, and Châtelet to put forward a new form of materialism that they term *inclusive materialism,* which also troubles traditional humanist and rationalist notions and takes up the aesthetic, affective, and material as *mattering.* de Freitas and Sinclair put this theory, and others, to work to rethink school mathematics. They note four crucial aspects of inclusive materialism:

1. It is not reductive, seeing all matter as the same; instead it privileges "difference and multiplicity" (p. 42).
2. The socio-political and the material are seen as "inextricably entangled" (p. 42) and in this viewing inequity issues in education can be addressed within a broader framework.
3. Affect and aesthetics and nonsense are central, and rationality is not privileged.
4. Humanist notions and human agency are decentered (not as anti-human) but to distribute agency across the assemblage.

Inclusive materialism functions in de Freitas and Sinclair's (2014) work to allow them to conceive of school mathematics as reconfigurable into what they imagine as a *minor* mathematics that is "not the state-sanctioned discourse of school mathematics but that might be full of surprises, non-sense and paradox" (p. 226). This reimagining is an ethical move for them, although they recognize that this mathematics will be: "at odds with current institutional demands. However, a minor mathematics is likely to engage students and teachers in more expansive ways, and our hope is that it would engage *more* students in mathematics" (p. 226).

Inclusive materialism insists that mathematical concepts are material and inventive. de Freitas and Sinclair use Baradian concepts to question the apparent immobility of matter and the construction of fixed bodies of knowledge. They propose that inclusive materialism might "alter the way we think about embodiment of mathematical concepts, offering alternate ways of studying how students learn concepts and how we might choose and order concepts as part of a curriculum sequence" (p. 12).

de Freitas and Sinclair (2014) animate matter and concept in material intra-action and disrupt the traditional view that learning happens in a fixed trajectory toward "immovable mathematical concepts" (p. 40). Instead, they posit that concepts emerge through activity and should not be taken for granted as standing apart from children and the materials with which they intra-act. In their view, the traditional trajectory of curriculum is upturned in favor of sensational (not just sensible) learning that is inventive and intra-active. They question the taken-for-granted curriculum in school mathematics. In intra-action, curriculum is understood as constructed and having effects on mathematical learners as learners have effects on *it*, and learning must be rethought as "an indeterminate act of assembling various kinds of agencies rather than a trajectory that ends in the acquiring of fixed objects of knowledge" (p. 52). Students are then acknowledged for their part in creation of mathematics, though the human is decentered, the student is given different agency than in traditional classrooms where knowledge is handed down as an inert object. In this model, teachers cannot think mathematical concepts separate from students and at a distance. Concepts/students/teachers/material/gestures are becoming together.

As in the review of poststructural theories, in thinking with Barad and inclusive materialism a new conception of methodology becomes necessary. de Freitas and Sinclair (2014) argue that taking up inclusive materialism would ask mathematics education researchers to reconsider the ways that they study how students learn concepts. They assert: "when concepts

are animated differently, learning is similarly altered. Inventive acts in classrooms become part of a growing material assemblage, a process of embodiment in which the *potentiality* of the body is emphasized" (p. 12). They speak frankly about the power that inclusive materialism could have to reconfigure school mathematics in ways that matter as they engage students in creative and relational mattering. They also illustrate ways that their research practices changed as they considered what was happening in intra-action. Instead of conceiving of a child learning on an iPad and *the* effect of that technology on achievement, they thought child/iPad/finger/table/number/researcher in intra-action becoming together and how that might matter. In this framework, educational researchers cannot separate out technology as a single variable that has a direct and measurable impact on the equally measurable learning of the child. The technology in intra-action with the child, mathematics, concepts, researcher, materials that con-constitute each other through that intra-action.

Ethico-onto-epistem-ology in Mathematics Education Research

Although Barad's conception of onto-epistemology and the collapsing of knowing and being are important and productive in how I think mathematics education, given Gutiérrez's (2017) and D. B. Martin's (2015) demands, it is Barad's inclusion of ethics and her view on responsibility that could really *matter* for students and researchers in mathematics education. Her concept of intra-action demands a relational ethics, as being and knowing are entangled, so, too, is living well and in respons-ability to all others. Barad (2007) proposes—

> *ethico-onto-epistem-ology*—an appreciation of the intertwining of ethics, knowing, and being—since each intra-action matters, since the possibilities for what the world may call out in the pause that precedes each breath before a moment comes into being and the world is remade again, because the becoming of the world is a deeply ethical matter. (p. 185)

In other words, educational researchers cannot separate ontologies, epistemologies, and ethics. They are entangled in the production of our worlds and our lives. Hillevi Lenz Taguchi (2009), a

childhood educator and researcher who has been taking up new materialist theories and particularly Barad's concept of intra-action in her thinking of school-nature-childhood entanglement, asks: "*what reality* is invoked and materialized before us depends on what ontological and epistemological position we take?" (p. 160). The responsibility then of *ethico-onto-epistem-ological* choices that are *made* in intra-actions become paramount as educational researchers are reconfiguring the world as we move with it. These complex and entangled choices cannot be made in advance. As Neyland (2004) attests, "the primary ethical domain is not monotonous, regular or predictable; it is shot through with uncertainty and contradiction and cannot avoid ambiguity" (p. 61).

As researchers make choices in how we live and research we are according to Barad's (2007) agential realist philosophy, making cuts. We are engaged in boundary-making practices that categorize and classify: "Cuts are enacted not by willful individuals but by the larger material arrangements of which 'we' are a 'part'" (p. 178). These cuts have material effects. For example, in Gutiérrez's (2008) work around the achievement gap, she points to cuts that are made around black and brown bodies that produce them as deficient and lacking. Cathy O'Neil (2016) argues convincingly that the way that statistics and mathematical models are used have material effects on people's lives and discriminatively negative effects on the poor. She shows how mathematical models are "not only deeply entangled in the world's problems but also fueling many of them" (p. 2) and the models used extensively today "tend to punish the poor" (p. 8) and perpetuate cycles of poverty, causing "widespread damage that all too often passes for inevitability" (O'Neil, 2016, p. 200). Far from being an abstract and static discipline that it is sometimes assumed to be, mathematics is intimately entangled in our lives as it continues to serve as a proxy for truth and privilege. The way that data/mathematical models are used and the

way that we do qualitative research matters. The models that we set up, in Barad's (2007) terms—the apparatus within which we are entangled—determine reality (O'Neil, 2016).

In each intra-action, then, researchers determine reality and reconfigure the world. These determinations cannot be made ahead of time and cannot be rule-bound or universalized. As Lenz Taguchi (2009) explains, "such universal ethics will not be understood as universally ethical by all, and second, such questions exclude the possibilities of asking ourselves how *can* or *might* we all live in different and other ways?" (p. 178). This question brings us back around again to Gutiérrez's (2017) call for different knowledges to be privileged in mathematics education research, D. B. Martin's (2015) call for a rethinking of equity for the Collective Black, and de Freitas and Sinclair's (2014) call for radical reconfiguration of school mathematics. As educational researchers, how do we work to continually pose questions to ourselves/each other that take into consideration how we might all live differently?

Ethics and Living Differently

Mathematics is always already in intra-action with theory, as constituted by and through and with it. Which theories are allowed to count (D. B. Martin, Gholson, & Leonard, 2010), how we count them (A. Martin & Lynch, 2009) in mathematics education research and who disciplines the field is driven by the political, social, and material. Stinson and Walshaw (2017) asked as they ended their chapter in the compendium:

> [Will] the battles over the nature of knowledge, truth, reality, reason, power, science, evidence, and so forth…continue indefinitely. Or might the battles wane, as mathematics education researchers, funding agencies, and policy makers come to a different understanding of "what works"? How do we, the community of mathematics education researchers, learn to evaluate science across paradigms? How do we learn to use science that produces different knowledge differently? (p. 147)

When I think this question, I wonder how I have thought across paradigms and how in this chapter, I have privileged particular versions of science. As I propose that mathematics education researchers should think with and in different knowledges, I want to bring forward Gutiérrez's

(2017) proposal and acknowledge the Whitestream (p. 4) within which my research is situated. I have read Kimmerer's (2013) and Anzaldúa's (2015) books, but I have to more carefully think their epistemologies in intra-action with mathematics education. Gutiérrez "suggests an epistemology of knowledges, underscoring the view that all knowledge is legitimate, partial and interdependent" (p. 6). She was careful to point out that the "production of knowledge is an ongoing process that is not cumulative but relational" (p. 7). Though Gutiérrez drew on biology, not quantum physics and reciprocity not intra-action, the *mathematx* she proposed is similar to Barad's (2007) *ethico-onto-epistem-ology*.

In this chapter, I focused on Barad's (2007) intra-action, I believe that the possibilities for how we conceptualize an *ethico-onto-epistem-ology* are only limited by our imaginations and or purposeful intra-actions with others/ourselves/objects/material. I read Gutiérrez's paper diffracted through Barad and de Freitas and Sinclair (2014) and came to think/be/write differently through that intra-action. Her ideas, and Kimmerer's (2013) and Anzaldúa's (2015) came into intra-action, and I am becoming with them.

Therefore, my call it is not that the mathematics education community make room for theory in mathematics; theory is already there/here. Instead I echo, Gutiérrez (2017), de Freitas and Sinclair (2014), and D. B. Martin (2015), that school mathematics needs radical reconfiguration and the "dominant" mathematics that plows through needs to be reimagined. It does not need to (and cannot) take up one particular right way. However, if knowing, being, and ethics are inseparable, then we operate in intra-action in and with mathematics in a deeply relational ethics. As Hultman and Lenz Taguchi (2010) explain:

> our engagement with the world, as researchers has *real* consequences. These are consequences that might evoke new realities and new ways of being, which in feminist and political perspective is of vast importance. What we do as researchers *intervenes* with the world and creates new possibilities but also evokes responsibilities. (p. 540)

Karl Hostetler (2005), when considering the question of good educational research states, "to each of those scenarios, we can and must say, 'Okay, but how does that serve people's well-being?' And to answer that question, we have to venture wide-eyed and strenuously into the 'bewildering complexities' of human good" (p. 19). With Barad and Gutiérrez, Hostetler's question is further complicated with the addition that we "learn from other-than-persons, which, in turn, may change our relationships with them" (Gutiérrez, 2017, p. 2). Being human now requires a more than human awareness to create radically reconfigured realities. I believe in mathematics education research and in lightness, joy, and play. Taylor and Blaise (2014) ask researchers to

> be a bit more flirtatious with the non-human world. For it is only if we can risk not already knowing, and keep a space open to the ways that the world might move us, that we can continue to be disconcerted, baffled and generally stimulated and enlivened by its inherent queerness. (p. 389)

So, rather than ask mathematics education researchers to take up new theories toward a particular goal, I propose that we as mathematics educators be open and uncertain about what possibilities thinking/being differently in ethical relation with mathematics education might open up. Barad (2007) attests, "ethics is therefore not about right response to radically exterior/ized other, but about responsibility and accountability for the lively rationalities of becoming of which we are a part" (p. 393). Research over the last few decades has shown that reconfiguration is possible, and we may have to unlearn some of what we *know* to achieve the radical reconfigurations.

CHAPTER 3: METHODOLOGICAL AND MATERIAL INTRA-ACTION

Karen Barad's (2007) ethico-onto-epistemology foregrounds the methodology of this study. Ethics, knowing, and being are in intra-action in the creation of this research, and I have become with the research as it has become with me. We mutually constitute each other in our on-going becomings.

In the qualitative research community what counts as data[59] and the ways that we can do research[60] are being broadened. In the mathematics education research community, there have been recent calls for other types of knowledge to be accepted (Gutiérrez, 2017) and to broaden what counts as mathematics education research (D. B. Martin et al., 2010). The methodological moves that I have made in this dissertation project are possible because of the connections across the fields of qualitative research and mathematics education.

Even with a desire for opening boundaries and broadening perspectives, questions of validity continue to surface. Researchers within a field and across fields have the accompanying desires of wanting to do research that matters to them and to have a sense of whether the research will be accepted by the field. Measures of objectivity, validity, reliability, are designed to meet this desire. What data counts? How much is enough? Do methods need to be replicable? What counts as research? What counts as science? How do we come to know? How do the ways we come to know matter?

In this chapter, first, I consider the current conversations around validity and objectivity in qualitative research and mathematics education research. Then I outline the methodology of

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[59] See, for example, Bridges-Rhoads and Van Cleave, 2013; Denzin, 2013; Denzin and Lincoln, 2018; Jackson, 2013; Koro-Ljungberg, MacLure, and Ulmer, 2018; MacLure, 2013b; Nordstrom, 2015; St. Pierre, 2013.

[60] See, for example, Jackson and Mazzei, 2012; Lenz Taguchi and St. Pierre, 2017; Smythe, Hill, Dagenais, Sinclair, and Toohey, 2017.

the original study in this project. Next, I tell the story of how that research was disrupted by theory and by a poem in Barad's *Meeting the Universe Halfway*. I then pause to consider and wrestle with Barad's conception of objectivity and her knowledge making apparatus. From there, I introduce the diffractive methodology that works as the framework for the dissertation. Finally, I argue for how the knowledge making apparatus within the methodology might function.

night driving

i am squinting at the light all around
illuminating something, but always the wrong things
on back roads between
Smithfield and
Richmond

my father taught me to look at the white line
at the edge of the road
watching for the green eyes of deer
or fox
listening to stories of old girlfriends and
transmissions destroyed by fields

don't look straight on or you can't see
i look instead in the mirror
flip the switch for night driving
again a blur
an outline
thick

im not sure where the real line is
there is a ghost of a car
i know it is there but i don't believe it

i never trusted mirrors, a driver's ed teacher telling me not to look over my shoulder
use your mirrors

i still dont
searching for some clearer version
some
bit of
truth

A Brief and Personal History of Validity

Questions of which truth matters, what data can be used to support or undermine particular claims, and who decides which truth counts have become increasingly important in today's political and educational climate ("Conway: Press Secretary Gave 'Alternative Facts'" 2017; Robertson & Farley, 2017, January 23). These questions are being taken up in the qualitative research community (Koro-Ljungberg & Barko, 2012; Koro-Ljungberg & MacLure, 2013; Manning, 2016a; St. Pierre, 2018). Whose truth gets to count and how, is an ethical/political matter.

I carry with me into this research marks on my body from my readings, experiences, writings, conversations, and material interactions as a part of the ongoing becoming of the world. I do not adhere to the belief that I can write or think from one particular theoretical perspective, so I acknowledge that I bring into this dissertation humanist, poststructuralist, and posthumanist ways of knowing that are not cleanly bounded from each other. As much as I have, over the last 5 years, wanted to push away my humanist thoughts or notions, they have a persistent pull. Even when temporarily distanced as I attempt to be a "good" poststructural or posthumanist subject, they find a way to drift back into the specific material configurations within which I am working.

In intra-action with poststructuralist and posthumanist[61] theories marks have been enacted on my body and pieces of my body have been removed, so that I might be a reliable knower in other aspects of my life. Since I was a small child, I have had many experiences of being distanced from my body and or told how I should or should not feel in bodily entanglement with others and what should be acceptable to me. For the better part of 35 years, I was disciplined into

[61] I use posthumanist here as an umbrella term with includes new materialist theories. There are ongoing debates in the field about terminology and posthumanist being beyond human. I use it here because referring only to new materialist theories would exclude some authors I was thinking with such as Rosi Braidotti (2013).

not relying on my feelings or thoughts or desires as being valid. Others got to tell me what I was supposed to feel and when I was allowed to be upset.

More recently in the last 3 years, Google search results, numbers on medical reports, and lab test results have all played a role in my reliability as a knower. I was told that I could not know the truth about my feelings because of these numbers. These facts matter in the specific material configuration of this dissertation. Numbers have been used against me. They have made me feel small and powerless. My body/mind was not mine to know. So perhaps it is not a surprise at all that in this work I am taking up and arguing for the acceptance and recognition of various forms of knowledge and for educational researchers to carefully consider what they deem acceptable and legitimate. Knowledge making practices are specific material configurations, and they include much more than researchers typically acknowledge as mattering. The question of who can know and what they can know is a deeply embodied question. It matters how knowledge is produced, who produces it, and for whom.

Numbers have power in our knowledge making practices and those numbers are constructed in intra-action with counting practices (A. Martin & Lynch, 2009) and orientation toward linear models of growth and progress (Llewellyn, 2015). If they are not concerned with direct counts, researchers are still concerned with amounts. Is there enough data for rich descriptions? How many interviews were conducted? How many minutes long were they? How many participants were interviewed? So even as some educational researchers have moved away from quantitative research methods, there is still the question that lingers—how much is enough? And how do we tell? What counts as good qualitative research?

James Scheurich (1996) referred to the attention toward reinventing reliability frameworks in qualitative research such as Lincoln and Guba's (1985) "credibility, transferability, dependability, and confirmability" as masks of validity. They are masks because

they still rely on binary conceptions of good versus bad research, and those determinations are often dependent on the amount and types of data and how that data is processed to create an accurate representation of the object of study. Scheurich asserted that new imaginaries are needed to "unmask and undermine dualistic regularity" and "highlight, support, and celebrate polyphony, multiplicity, differences and the play of the other" (Scheurich, 1996, p. 56). In the methodology of this dissertation, I aim to play seriously with difference and highlight multiplicity toward the goal of more equitable mathematics education research.

As suggested by Bullock (2012), the how and why of a researcher's method is crucial if mathematics education researchers are to take up "good" equity research in mathematics education. It is not enough to assert that different ways of knowing need to be accepted or recognized. This dissertation work is not about inventing methodologies for the sake of innovation, the innovation comes out of the inequities I felt and saw in my 19 years in the field of education in various contexts, from the way that students came to me in 8th grade beaten down by the ways of knowing that were acceptable in mathematics classrooms up to that point. The ways that they had to hold their bodies and voices and imaginations to be accepted and acceptable in those spaces. The reconfiguration of methodology in this dissertation comes from the need to radically reconfigure mathematics classrooms for marginalized populations. The need for students to be not just given access to mathematics, but to be invited into mathematical thinking, to be seen and recognized as capable and critical readers and writers of mathematics. So, a methodological question that serves as a refrain in this dissertation, is how does, might, could this research matter for students in and out of mathematics classrooms? To get there, I begin with the story of how I came to this research and how it matters for me.

> It matters what matters we use to think other matters with;
> it matters what stories we tell to tell other stories with;
> it matters what knots knot knots; what thoughts think thoughts,
> what descriptions describe descriptions,
> what ties tie ties.
> It matters what stories make worlds,
> what worlds make stories.
> (Haraway, 2016, p. 12)

Intra-action that Produced Phenomenon of the Original Study

The original study that produced the data that are taken up in this dissertation was a result of my engagement in three qualitative methods classes at my university, my disciplining into the neoliberal academy, and a chance encounter with a former colleague, among many other unnamed factors and influences. I ran into the former colleague, who has become Elisabeth in this dissertation, and I asked her how her year was going. She was palpably excited about the opportunity she had had to teach a new course at her school. In the class, she had studied current events with students and considered how mathematics was used to describe events and how it might be used to better understand events in the media. She thought that the class had really mattered for the students and made a difference in how they thought about the world. Teaching it made her feel like she was doing something to address all the injustice that was happening at the time. This chance encounter happened in the spring of 2015 and the class had investigated the protests after Michael Brown's murder in Ferguson and the rates and ratios of police stops in the county. They had studied the Marriage Equality Act and Gender in the Gaming Industry.

At the time we spoke, I had just finished a review of social justice literature in the field of mathematics education and was about to take a summer class on case study research methods prior to taking another qualitative research methods course in the fall. So, the phenomenon that is my study and the specific material arrangements of the knowledge making apparatus that is my dissertation were born out of these moments. The original research has produced cuts and marks

that need to be attended to. It is therefore important to acknowledge and describe those configurations, prior to considering the reconfigurations.

Initial Data Production

In the original study, the study I designed, I was operating between the understand and emancipate paradigms (see Figure 16). I wanted to know with certainty what was happening in the classroom and to be able to say something true about teaching mathematics for social justice (TMfSJ). I also believed that the study was important in how it might be able to shift how teachers conceive of what counts as teaching mathematics in middle school. I come back to Figure 16 in Chapter 4.

TABLE 6.1. Mapping Moments of Mathematics Education Research to Paradigms of Inquiry

- Process–Product Moment (1970s–)→*Predict*
- Interpretivist–Constructivist Moment (1980s–)→*Understand*
- Social-Turn Moment (mid 1980s–)→*Understand* (albeit, contextualized understanding) or *Emancipate* (or oscillate between the two)
- Sociopolitical-Turn Moment (2000s–)→*Emancipate* or *Deconstruct* (or oscillate between the two)

Paradigms of Inquiry				
Predict	**Understand**	**Emancipate**		**Deconstruct**
*Positivist	*Interpretivist	*Critical		*Poststructural/
Experimental	Social Constructivist	<Feminist>		Postmodern
Quasi-experimental	Radical Constructivist	Critical Race Theory>		Postcritical
Mixed Methods>	Sociocultural>	Latino/a Critical Race Theory>	*BREAK*	Postcolonial
	Phenomenological	Critical Theories of Race>		Posthumanist
	Ethnographic	<Participatory Action Research		Post-Freudian
	Symbolic Interaction	Critical Ethnography		<Discourse Analysis

Note. *Indicates the term most commonly used; < or > indicates cross-paradigm movement. The BREAK in the original Lather and St. Pierre table indicated a shift from the Enlightenment humanist paradigms on the left to the post-Enlightenment, posthumanist paradigm on the right. Here it indicates a hybrid, in-between space where the researcher might adopt a critical postmodern theoretical tradition (see Stinson & Bullock, 2012, 2015). Paradigms of inquiry adapted from table by P. A. Lather and B. St. Pierre, 2005, found in "Paradigm Proliferation as a Good Thing to Think With: Teaching Research in Education as a Wild Profusion," by P. A. Lather, 2006, *International Journal of Qualitative Studies in Education*, *19*(1), p. 37.

Figure 16. Mapping moments and paradigms of inquiry (Stinson & Walshaw, 2017, p. 133).

Context.[62] The site of the study is a small middle school that serves nearly 200 students in grades 6–8. The school is located in a large southeastern city within five miles of the urban center. The school is housed in a refurbished school building. The school is a long-established charter school. Thirty percent of the students served by the schools at the time were eligible to receive free or reduced-price meals. In terms of racial demographics, the school reported to the state for the year that the student body was composed of 74 Black students (37%) and 124 White students (63%). I knew the site well, as I taught there for 5 years prior to attending graduate school. There was a one-year gap between my leaving the school and my return for this study. This school operated with the Coalition of Essential School's Ten Principles, which prioritize relationships, deep curriculum, and democratic ideals. In general, the teachers at the school developed their own curriculum, although there were some purchased curriculums. To meet the demands of requirements for Student Support Team (SST) and Individualized Education Plans (IEP) the school had initiated a Learning Acceleration Period (LAP) a couple of years before I left. This period was a 30-minute class that took place four times a week. A team of teachers and administration would look at testing data and consider recommendations from teachers to place students in courses that would support their growth. There were a variety of courses from reading and math support to quiz bowl and computer literacy. The classes were composed of mix-aged groups of students from all three grade levels in all classes. This site was chosen because I heard about a particular LAP course from one of my former colleagues (as previously noted).

Researcher positioning. I am a 40-year-old White middle-class woman. I taught at the school site for 5 years, prior to the beginning of this study and taught 13 years in total in urban schools. I was a Math Science and Technology (MST) teacher for sixth- and eighth-grade and the

[62] In the following few sections, I write about the context and my positionality as I would have and did in my initial writings about the research such as the IRB proposal.

content team leader for MST. As the content team leader, I supervised a team of six MST teachers providing formal and informal feedback on their teaching, organizing the curriculum and assessment strategies for the team, and looking at student data with the team. I taught LAP courses on reasoning and problem solving. As an insider at the site, I had a depth of understanding and knowledge others may never achieve, but I also brought the biases of my particular place in a well-established society and could mistake "conventional wisdom" for data (DeWalt & DeWalt, 2011, p. 168).

Current Events Math course. The course that was of interest was entitled Current Events Math. It was initially described to me by one of the teachers. She said she had taught an enrichment course for mathematics LAP in which the students studied things that were happening in the news and then used mathematics to better understand the events, or considered the data and statistics that were presented in the media and how those statistics were created. She described a few of the topics that they had addressed in the previous year and described how being in the course seemed to change how the students interacted with mathematics and the news. During class sessions, the students and teachers explored a current event topic for 2 to 3 weeks using mathematics to consider different perspectives on the topic.

Participants. The course was taught by two teachers to two groups of students over a 10-week period. Each class had approximately 15 students aged 11–14 (grades 6–8). One teacher was a middle-aged, White woman with 5 years of teaching experience. The second teacher was in her first year of teaching and self-identifies as Pakistani-American.

Purpose.[63] The Common Core Standards for Mathematical Practice[64] and the NCTM Standards (e.g., NCTM, 2000) have called on educators to increase discourse in mathematics classrooms and to engage students in mathematical arguments and discussions. The Association for Middle Level Educators[65] have called on teachers to "demonstrate the interdisciplinary nature of knowledge by helping students make connections among subject areas" (p. 5). With these charges, examples of the integration of these practices are needed for consideration, reflection, and discussion. TMfSJ encourages mathematical discourse and engagement with content from the lives of students across disciplines (see, e.g., Wager & Stinson, 2012). Gregson (2013) noted that of the current research on TMfSJ there are few studies of fulltime teachers working in the field. The Current Events Math course asked students to consider which current topics are of interest to them, research the data related to the topic, use mathematics as a tool to evaluate that data, and then consider the issue more fully. Although the teacher did not define the course as TMfSJ, I take the view of Wager and Stinson (2012) that we do not need to delineate or define social justice, instead we need to "provoke more questions and to stimulate new discussions about the many meanings of and possibilities for teaching for social justice" (p. 5).

Original research objectives

1. To explore how students interact with current events with and without the use of mathematics as a tool to make meaning of the implications of the events.
2. To explore how students' perceptions about their relationship to mathematics and its purpose change through interaction with the coursework.

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[63] This section and the following are taken directly from my IRB. As you will note, the purpose and research questions shifted. I include these here to illustrate that shift.

[64] See http://www.corestandards.org/Math/.

[65] See http://www.amle.org/aboutamle/professionalpreparation/amlestandards.aspx.

3. To explore the teacher's interaction with the students and her perception of the role of mathematics for them and her in considering current events.

My primary research question concerned uncertainty, how does uncertainty present itself in mathematics classrooms and how is it handled? Other secondary research questions included: Of what are teachers and students certain? How do their beliefs change over time when engaged with mathematics? Why would a teacher engage students in constructing curriculum? How do teacher beliefs about mathematics change through interactions with students?

Methodology. I was particularly interested in potential differences across the two teachers considering that one teacher was a novice and might be less comfortable with uncertainty. I designed a comparative case study so that I could observe the novice and veteran mathematics teachers as they taught the Current Events Math course. Merriam (2009) defines case study primarily by how the researcher delimitates the object of study. She asserts that in case study research, the object of study is "a unit around which there are boundaries" (p. 40). Yin (2014) describes case study research as empirical inquiry that "investigates a contemporary phenomenon (the 'case') in depth and within real-world context, especially when the boundaries between the phenomenon and context may not be clearly evident" (p. 16). Merriam's definition requires boundaries, yet Yin accounts for the fact that the boundaries are not clearly evident and must be made by the researcher. In this study, I defined the overarching case as the Current Events Math course. Within that overarching case, I compared the two sections of the course.

Interviews and transcriptions. At the beginning of the study, prior to the beginning of the course, I conducted semi-structured interviews (Merriam, 2009; Roulston, 2010) using an interview guide (see Appendix A) with each of the teacher participants. I transcribed the interviews and read them and took notes on them prior to my second interviews. For the second interviews, I used photo elicitation (Harper, 2002) and also followed up on questions from the

initial interview. I conducted a third interview after the course was completed that consisted of open-ended questions.

Classroom observations and field notes. I entered the field and visited each classroom weekly for the duration of the 10-week course and took field notes and made observer comments on those field notes (Bogdan & Biklen, 1997). The classes were taught simultaneously, so I could not observe the whole class for both classes on one day. Most days I would observe one class and then check in with the other teacher briefly before or after. I would then observe the other class another day that same week. Sometimes the teachers taught the same lessons on the same days and other times, they would be out of sync, so sometimes I was able to see each teacher engage students in the same activity. I took notes by hand in a journal and then when possible would type up notes immediately following my visit. I also attended a planning meeting for the course mid-way through the semester in which both teachers participated.

In my early field notes, my remarks were primarily "objective" noting things that could be seen and pointed to or heard in the classroom. I was an "explicit observer" (DeWalt & DeWalt, 2011, p. 92). As I spent more time in the classrooms, I paid more attention "feeling and experiencing" (p. 92) in addition to noting and remembering what happened. I began to record "impressions, thoughts, concerns, explanations" (p. 166). I also became especially attuned to my behavior and reactions, wondering when I should step into the role of participant observer and when I should draw back.

Document analysis. The two teachers collected all student work completed over the 10-week course. They saved the documents in folders by unit and blacked out the students' names. As I conducted the analysis of these documents, I began with Prior (2003): "a document and especially a document in use, can be considered as a site or field or research in itself" (p. x). Document analysis was chosen for this study in part because the Current Events Math course

took a stance to look closely at and question documents (photographs, graphs and charts, newspaper articles, and statistics).

Theoretical and Material Interuption and Paradigm Shift

I conducted this research under the direction of a qualitataive research professor who took poststructural theories seriously and while taking Poststructural Inquiry with another professor. So, it was not long before what I intended to do bumped up against the material/theoretical. The moment that seems to be at the center of this shift was late one evening while I was transcribing an interview.

> Typing with my eyes closed barely breathing listening to voices and background noise and my fingers on the keys
> My nails are too long
> My wrists are marked by the edge of the metal wrapping on this box
> Pinkies stretch to pause to play back to remember
> Fingers fly and know not what they do
> Data emerges
> Is it
> Chunked and clunky never-ending
> No time for periods or capitals or paragraphs
> Do we speak with periods?
> With capitals
> do I say
> What are you up to today?
> Or
> what are you up to today?
> the computer autocorrects
> is it the computer who makes my W big?
> what if I want it small?
> can you hear me
> is my voice clear
> have you captured me on
> audio, on
> keyboard, on
> screen,
> in 00000000s
> and 111111s
> what's my file name
> what folder is my home
>
> I am keeping my broken down broken up version
> Maybe ill have to make another one for someone

But im keeping mine with the stops and starts and mistakes
Can I keep the cursor's blinking line if this goes to print?
It says, what next
We're not done
Hey, give me back my little w

The givens of qualitative research, the methods that seemed so neatly outlined in my textbooks—recruiting participants, conducting interviews, and listening to and transcribing interviews—elicited more uncertainty in me than I expected. I had interviewed and transcribed before and as part of a research team and was given clear expectations and routines for each part of the process. I felt removed from responsibility for the project and more like a cog in the wheel.

When I began by interviewing, Elisabeth, a former colleague—friend, parent, mother, construction worker, goat cheese maker, mathematician, scientist, poet, rock lover—we sat on the couch in my bedroom/office with glasses of wine in our hands. We talked, or she talked. I was, at the time, still convinced that I needed to take a neo-positivist approach to this encounter. The less I said the better. As the interview tape ends, I hear myself saying:

I didn't say much
did all right though
I kept asking yes or no questions
which I'm not supposed to do

The context of the second interview was very different. I sat across the desk from Ayesha in her classroom and 5pm in the evening. The school was empty except for us and the custodial staff. I was more timid, hesitant to start the interview wanting to make sure she was comfortable, not wanting to seem rushed to extract the data from her. The idea of data as something I take was in my head. That's why I should not talk too much, insert myself too much. It would taint the data. Even in the second interview, I continued to hold firmly to this stance, this measure of a successful interview as the participant talking and me listening. Does this make what she said

more true or honest or more like data? Or does it make it less real? I cannot erase myself from the encounter. I cannot ask them to unsee me, so why do I hold back?

The truth.
Validity.
Take me seriously.
Believe me.
Know this.

I had been brought up in the structure of positivism. There is one truth, one answer, a singular, linear method that results in knowledge. It is hard to break those habits to see past the things that I do unknowingly or rather knowingly. As I interviewed and looked at the person across or next to me, I wanted to keep them safe to protect them, yet I needed to take from them, their data, their words. I had the interview guide in my hands. I took notes here and there of things I wanted to come back to, threads I wanted to pull. While simultaneously, I also looked to it to make sure that I *got everything* I came for, to make sure I *finished.* I was between. I was uncomfortable.

I transcribed my second interview first. It was hard to hear, I had decided to try recording on my computer without testing it. The A/C was running and running. I remembered the other teacher who taught in that room always complained about how loud it was, no wonder the new teacher is in there now. Isn't it the tradition of schools that we swap up to better rooms when new teachers come in? I strained to hear her, to capture what she was saying. I do a first run through just typing what I hear before going back through to refine. When I started back through, I wondered where periods should go, and do I keep all those ands? How does the way that I re-present her speech influence how it is read? I choose not to make it completely formal. The ands were there, they seemed important in a way, they indicated that she was building on something said before a continuation of thought, rather than a new idea. But mostly it was like all the transcripts I had seen before. I was uncertain.

As I typed up the first interview, I was a couple hours in when I looked back up at the rough text. I was using InqScribe, which allows me to slow down the playback to 60%. What am I missing of the other 40%? Our voices are elongated and strange. I still cannot keep up with the typing. There are two panels, one with the controls for the playback and the other a plain box where the text sits. In that box there were these piles of letters chunked together. As I listened to her voice, that didn't seem right. It did not match the cadence, the rhythm of the talk, so I started using the enter key to break up the text along with her rhythms, her pauses, her enunciations. It became poetry instead of text. It came alive and seemed more resonate of her. I paused to write lines at the beginning of this section. I decided to leave the transcript, messy, to think of it as a tracing of my wondering. I scrolled through the transcript moving quickly from the chunky piles of text to the sparse lines below. They looked to me like the reading from an EKG, the heartbeat of the interview, the life that was in it. Maybe, I'm a romantic.

Here I found some solace and more questions in what Mary Bucholtz (2000) shared about transcription:

> The choices made in transcription link the transcript to the context in which it is intended to be read. Embedded in the details of transcription are indications of purpose, audience, and the position of the transcriber to the text. (p. 1440)
>
> What may be less obvious is that the interpretation of a recording cannot be neutral; it always has a point of view. (p. 1441)
>
> But they are also representational insofar as they offer a version of events and a portrait of the participants in those events. (p. 1444)

Although I knew in one sense that the transcripts would not and could not represent fully, accurately, completely the interactions with the participants, I also knew that it would be *a* representation of that interaction that an audience would take up at some point and consider. Koro-Ljungberg (2015) asserts, "data is fluid, a chameleon, able to take different 'shades' of meaning based on the perspective of the researcher" (p. 47). So, the transcript was one

representation of the interaction, and I wondered what else was possible and how might those different representations matter differently for how the participants, the study, and the course are taken up by audiences (see Figure 17). I took up this question elsewhere more fully (Cannon, 2018).

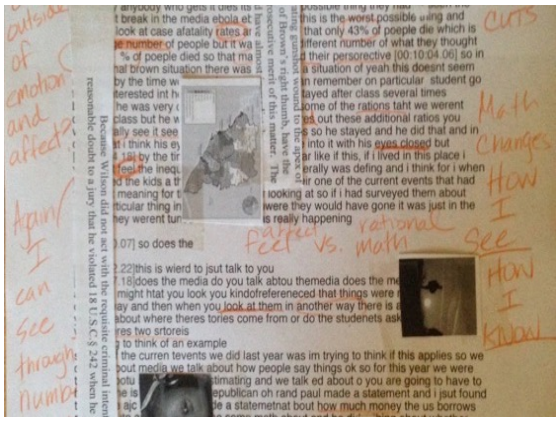

Figure 17. Transcription iteration collage.

I wonder if it was different because Elisabeth was a friend. Elisabeth and I came to the school at the same time 7 years ago, and we taught together for 5 years. For part of that time, I evaluated her because of my role as the head of the math and science department. We also had many dinners on my back porch. Did I feel more responsibility to her because of this? In my first weeks in the field, I felt tensions in working with her. After my first observation of her teaching for this study, I pulled her aside and asked if it felt weird to have me there. I wondered aloud whether it was strange given that when I came to observe before I was evaluating her teaching. She assured me that she was just glad I was there and wished I could be more involved. After our interview, she said to me: "That was a gift, really a gift. I haven't talked about this before." I did not capture that statement on the recording device. Yet, it mattered for my relation with her. I thought of it as a gift as St. Pierre (1997b) conceptualized it:

> All these others move me out of the self-evidence of my work and into its absences and give me the gift of different language and practice with which to trouble my

> commonsense understanding of the world. They help me move toward the unthought. (p. 185)

I believe that the gift was that Elisabeth received my attention. She was listened to and her work was taken seriously. I asked questions of her and wanted to know more about what she was doing and why. From having been in public schools for 13 years, it has been my experience that teachers are not often listened to or seen as holders of knowledge about their classrooms and students. Instead, they are given external measures to attend to and to determine their effectiveness. I think this asking and sharing is a rare experience for a teacher.

With Ayesha, the relationship was different. I had met her briefly on social visits to the school the previous year, but we had never talked. She entered into the research on Elisabeth's recommendation, and I think trusted me because she trusted Elisabeth. She began the interview wanting me to know that she was very new to teaching, that she did not have much experience. There was a self-consciousness and a seeking of approval. Then in the middle of the interview, I realized just how comfortable I felt in her space, this place I used to work, these rooms I knew so intimately, even the habits of the air conditioners.

> (*Custodian comes to door and asks to get the trash.*)
>
> **Susan:** I don't mind. (pause) Do you mind? I should have let you answer that question because it is your classroom.
>
> **Ayesha:** No, it's your interview.

I knew the space. I had a confidence there. Yet, I did not know her at all. I could not know. In this space where I *became* the teacher I wanted to be, and now in this place of *unbecoming* teacher and becoming researcher. I felt connected to St. Pierre's (1997b) words: "I was both identity and difference, self and other, knower and known, researcher and researched" (p. 178). Am I both like and unlike these two participants and all that is between and around?

According to Sharon Todd's (2003) definition of responsibility, with which I was thinking at the time, I was making some decisions and moves that felt responsible. She said, "what counts as conditions of responsibility are therefore based in the quality of relations we have to others as opposed to adhering to predefined principles that we apply to the particular situations in which we find ourselves" (p. 141). I found myself considering the relationship I was creating between myself and participants and how to be careful in the ways I interacted in interviews. I felt a sense of responsibility to Elisabeth and Ayesha and continually checked in on them in terms of my choices.

In the text of the interviews, I look back at my choices, which were contextual and responsive to that time and place and critique them. As I move in the field, "ethics explodes anew in every circumstance, demands a specific reinscription, and hounds praxis unmercifully" (St. Pierre, 1997b, p. 176). I hear myself making a choice to listen, to pause and to make space for my participants to speak and asking for more. I had been working toward responsibility by attending to the people and their words:

> **Ayesha: ….** [00:24:33.15]
> (Four second pause)
>
> **Susan:** Thank you. [00:24:37.05]
> (Seven second pause)
> Um let's see [00:24:44.14]
> What are you hoping that students will take away from the course?

In the first interviews, I conducted, I would never have paused for that long. I felt the need to fill the space to keep it moving which resulted in a thoughtlessness that I did not like. Now, I asked follow-up questions:

> **Susan:** And when you say better you mean?
>
> **Susan:** Um ok you said I always ask why is it important why do you do that?

Although I did still find myself asking "think aloud" questions (Roulston, 2010):

> **Susan:** You talked a little bit about the students interacting in class. Can you tell me what you hope? What you want the class to look like in terms? How it's? Like what a day might look like in terms of interaction amongst students and what your role is versus what they students' role is?

Then later, I catch myself and stop:

> **Susan:** Can you tell me more about the layers of responsibility in the MST class? How you… Let me just stop there. I always do that where I ask like three questions. Tell me more about the layers of responsibility.

I wondered about the ways that I gave signals to Elisabeth and Ayesha, approval or disapproval. I heard myself judging and heard them asking, was that ok? Should I have responded to their statements with "uh huh" or "I see" or "go on"? If I approved, could they know that, wouldn't they see it in my face anyways? Or should I have been striving for a position of non-judgment of hearing and letting in and listening? I especially worried about my presence in terms of classroom observations. What do I say when I enter and exit the room? Nothing? Have a nice day? If I enjoyed the visit can I say so or will that make the time when I don't more obvious?

I agree with Koro-Ljungberg (2015) that I should not "avoid such situations associated with urgency and uncertainty altogether by delaying [my] responses or by attempting to verify [my] responses ahead of time"(p. 129). I had to decide in the moment. In listening to my September 15, 2015 interview, I wished I had acted differently:

> **Susan:** Is there something about your own story that you think makes that so important to you or?
>
> **Ayesha:** Um I think [00:26:16.29] I think like I didn't know of all these things growing up. I lived in this very, I grew up in Saudi Arabia and lived in a very naive and comfortable environment and I was. When I moved to the States, I realized I was the different one. And um that people would be different towards me. I was like if they just knew me.
>
> [00:26:52.22]
> **Susan:** Um
>
> [00:27:01.06]

Susan: How

[00:27:04.29]
Susan: Can we talk about math for a minute, so what is the role of mathematics in your course and what do you what are the important things in mathematics that you want them to leave this course with.

Ayesha: Oh my god. It's amazing oh I love math um I want them to be able to I want them to be comfortable with scientific notation I want them to be comfortable with big numbers and small numbers decimals and I want them to be comfortable with percentages and I want them to know that if you see a problem there is always a solution there has to be a solution so even if they get it wrong the first time they'll get it right eventually.

Looking back, I wonder what might have happened if I had probed, "If they just knew me." I paused. I thought about it. I think my reasons for moving on were two-fold. One, I was hesitant to get too personal on the first meeting, and two I was worried about staying on topic and getting through the interview and keeping it centered on mathematics. My whiteness[66] in that space certainly played a role as well. I think that the first reason might be legitimate; the second, in retrospect, seems counterproductive. This adherence to the interview guide, is it productive for me? I do not think it is. Here the participant was offering me something emotional and I turned back to content, to math. I shut down this person who is saying she feels unseen and different. In intra-action with me and my whiteness would she have continued if she had wanted to. I didn't see her or was not comfortable seeing her. Ethically, I signaled that her story wasn't important in the research. I wondered if I could come back around to this?

Later Ayesha questions herself:

[Lines 367–374]
Ayesha: Probably not even saying what… I have learned from experience, but I don't know if everything I am saying is the right thing. I just know it is whatever I have can observe from it.

[66] I had lots of conversations in a doctoral seminar I was taking around this time about who could and should interview whom. Interviewing a participant who identifies as Pakistani American as a White woman mattered.

Susan: Yeah that's all you can say.

Susan: I don't think there is a right. There are some rights.

Am I trying in some small way to reassure her? Later in the interview, I made another move that I look back on and question. I had an idea of what I expected or wanted to hear, and I pushed this upon her. I crossed a line, not because it taints the data but because I brought a worry into her perception of herself in the classroom that wasn't there for her before:

> **Susan:** I guess I'm also wondering about Teacher KEYS[67] and those sorts of things. Is that part of the layers of responsibility?
>
> **Ayesha:** I don't think of Teacher KEYS because I haven't been through it yet.
> [00:52:03.18]
> **Susan:** I'm sorry I raised it and brought it up.
>
> **Ayesha:** I should be thinking about that.
> (*Laughter*)
>
> **Susan:** I'm glad that you are not. I shouldn't say that. Do you want to stop there for today? I have a ton of other things I want to ask you about, but I think they go beyond the scope of what I asked you to talk about it.
> [00:53:03.03]

I was in a crisis of representation and was filled with uncertainty, and I wanted to do research in responsible ways. I wanted rules for how to do this work and I knew rules would not save me. I had some strange confidence that the uncertainty would be productive. I kept asking myself: "How do I do representation knowing that I can never quite get it right?" (Pillow, 2003, p. 176). I wanted to "work against normative practice and taken-for-granted assumptions" (Koro-Ljungberg, 2015, p. 20) and toward a positive careful practice. I was particularly drawn to St. Pierre's (2004) citing of Foucault:

> From that viewpoint, all my research rests on a postulate of absolute optimism. I don't construct my analyses in order to say, "This is the way things are, you are trapped." I say these things only insofar as I believe it enables us to transform them. Everything I do is done with the conviction that it may be of use. (pp. 294–295)." (p. 293)

[67] Teacher KEYS is the state performance measurement for teachers. It is a rubric with ten areas and several requirements for performance under each area.

I wanted my work to be of use and to be careful. I wanted better or at least different ways to represent, and I knew that there could be no adequate representation—it took me back to my thinking about models and how all models are abstractions—and we have choice and responsibility in what we abstract and how.

I needed another way to think research… that attended to difference… and complexity… It was amongst in these reflections and snags within the methods that I accepted an invitation to join a reading group with faculty and doctoral students in the elementary education department downstairs.

Moving Toward What Looks Like Nothing

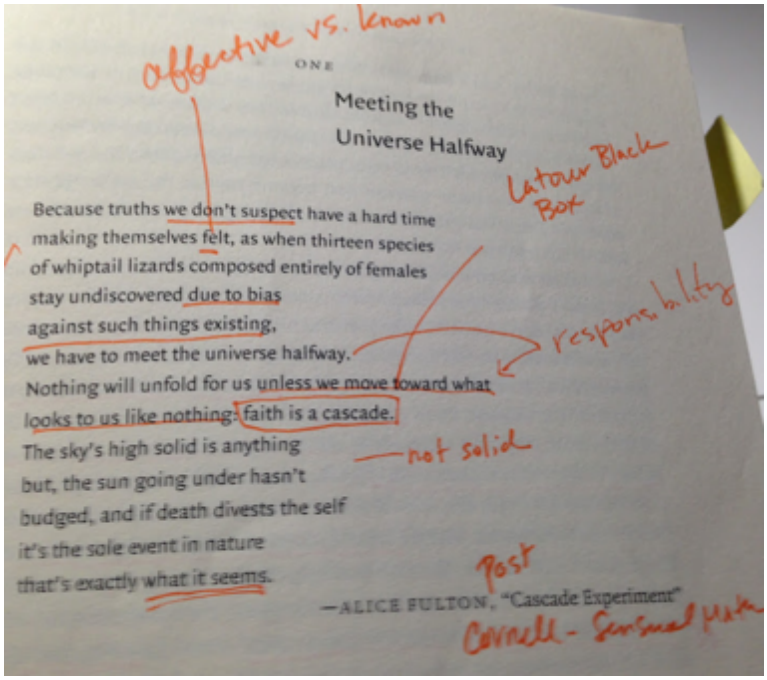

Figure 18. Image of page 39 of my copy of Meeting the Universe Halfway.

The poem, *Cascade Experiment* by Alice Fulton, in Figure 18 opens Karen Barad (2007)'s *Meeting the Universe Halfway* and in reading group one of the other members and I poured over it. It seemed to hold within its 13 lines all of the questions that I had been asking and

a promise of an answer or at least direction to move: *toward what looks to us like nothing.* Toward the unknown and into the uncertain. This move was a moment of hope for me. We turned to the full poem in the back of the text and studied it. What might this poem offer, what might this text offer, that might work against bias, that might allow for the witnessing of truths we do not expect. And this was a text by a physicist, a scientist…. How might she balance doing science and poetry? How might her science count? How might she validate her ways of knowing?

Barad's Objectivity

One of Barad's (2007) major projects in *Meeting the Universe Halfway* is to conceptualize objectivity building on Bohr's writings and philosophy physics. In humanist conceptions of science, there are stable subjects and objects with fixed and inherent properties. These properties and attributes can be described and measured. Here, the measurement or observation is outside the referenced object and its effect is either assumed to be negligible or is subtracted out of the equation. Conventional educational research practices, whether qualitative or quantitative, lean heavily on this framework. Barad proposes a reconfiguration of objectivity. She uses Heisenberg's and Bohr's versions of objectivity as reference points throughout her argument. It is worth the time to consider these in order to move into what Barad proposes.

Heisenberg proposed the uncertainty principle and the key to his argument was that the object of measurement, in this case an electron, was disturbed by the measuring tool, a photon. His principle relies on a limitation on what one can *know* at the same time. It is an epistemic concern. A person cannot know the value of the electron's momentum and position at the same time because the particulars of the measuring apparatus do not allow them to. This not knowing, however, implies that there is a determinate value to be known and it is just that one does not have the proper tools to be able to know. The value is determinate, but it is unknown.

In contrast, Bohr argued for the indeterminacy principle. In this view of objectivity, Bohr argued that one "can't know something definite about which there is nothing definite to know" (as cited in Barad, 2007, p. 118). Unlike Heisenberg, Bohr does not assert that the objects have determinate values that are inaccessible, instead he radically proposed that the properties themselves are indeterminate. The measurements are a result of their measuring apparatus and the measuring tool is included in that apparatus, therefore, the measurement is not inherent to only one particular part of the apparatus but to the overall phenomena that includes the object to be measured and the measuring device. This assertion is ontological as it addresses what can simultaneously exist and the stability of properties separate from their measuring devices.

Phenomena

Barad builds on Bohr's indeterminacy principle in her agential realist perspective. Barad proposes an agential realist objectivity that is determined by ongoing cuts together and apart Because this is an ontological assertion, it is helpful to begin with the primary ontological unit in Barad's onto-epistemology, phenomena. Phenomena are the "ontological inseparability/entanglement of intra-acting 'agencies'" (Barad, 2007, p. 139). The properties and boundaries of which become determinate through intra-action. It is intra-actions therefore that "enact agential separability" (p. 140). This enacted separability is the cut together-apart. The cut both separates the phenomenon and binds it as a unit. The cut is an ongoing enacted making and remaking, not in any way a permanent cut. A phenomenon, then, is in ongoing construction that reconfigures the world. In Barad's framework there is no inherent subject/object distinction or separation (p. 114).

This ongoing enactment of the subject/object distinction makes objectivity complicated. Yet, Barad (2007) asserts that it is possible. In order to have objectivity, a cut is made in the enactment of research that creates a subject/object distinction and the measurement is a part of

the phenomenon and produced along with it. Following this, I am in ongoing production as researcher in relation to the phenomenon and as a part of the phenomenon that is this knowledge making practice of dissertation. I am becoming with dissertation and becoming with participants and becoming with data in specific material arrangements. In Barad's take on objectivity the researcher needs to account for the specific material arrangements and the cuts that are made in the creation of the apparatus through relations with data, theory, texts, materials, and so on.

All measurements whether qualitative or quantitative[68] involve a particular choice of apparatus that provides the "conditions necessary to give meaning to a particular set of variables, thereby placing a particular embodied cut between the object and the agencies of observation" (Barad, 2007, p. 115). In other words, in entering my old school as researcher a cut was enacted that moved me from teacher to researcher and my colleague from friend to participant. In coming to the school to do research, I was choosing and enacting a research apparatus that gave meaning to my presence in the room, the notes I was taking, and the reports I produced. In the course of the research, I participated in evolving and shifting intra-actions within the larger apparatus of research that produced me alternately as friend, researcher, visitor, insider, colleague, belt repairer.[69] This shifting made responsibility in my ongoing intra-actions complex. It might have been easier if I had attempted to make a clean cut, to think in clean cuts between teachers and researcher. Research also might have been easier if I had followed an often-suggested rule of qualitative research: do not studied in a place that is too familiar to the researcher.

I am drawn to Barad's objectivity because it takes account of the material practices and boundary making involved in the enactment of the research apparatus. Yet, I have some

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[68] Although I separate these out here, I want to resist the binary between qualitative and quantitative ways of doing science as I think it is problematic.

[69] I expand on this subject/object intra-action in Chapter 5.

hesitancy about the use of objectivity as a term and how she justifies it. I cannot tell if my hesitation is due to the limits of language or the limits of her theory. Throughout the text she will describe concepts through the use of non-examples using the structure: the concept is neither …. nor…. Her theory and her objectivity operate in between and are therefore undefinable and cannot be pinned down. Through this language, Barad creates liminal spaces between meanings. Based on my writings in the Chapter 1, I should be comfortable with this betweenness. Yet, the humanist theories still are in intra-action with me and this dissertation, so I think—Tell me what it is. Define your objectivity. What are the limits? And I have to move back into thinking with Barad, and the onto-ethico-epistemological foundation of her theory. The inability to separate out knowing from being from ethics makes it impossible to pin down objectivity as anything other than relational.

In her objectivity, Barad (2007) states, "a semantic–ontic indeterminacy provides the conditions for the possibility of objectivity" (p. 120). This statement implies that knowing and meaning are both indeterminate. According to Barad then, objectivity requires accountability to permanent marks made on bodies. Measurements can only refer to phenomena, which includes "all the relevant features of the experimental arrangement" (p. 120).[70] They cannot refer to particular parts of the phenomena. Then in order to take or have a measurement have meaning, a researcher would have to assert that she knows the boundaries of the phenomenon of which the measurement is a part. Although researchers make cuts in their knowledge making apparatus that they are aware of, I assert that they also enact—or the apparatus enacts—many cuts that cannot

[70] Part of reason that I was drawn to statistics education literature to frame this dissertation is because of the ways Barad's descriptions resonate with the ways that statisticians think about their work. The specific arrangements of statistical models matter and are given attention in determining answers to statistical questions. I want to explore this arrangement further along with thinking with de Freitas, Dixon-Román, and Lather's (2016) ideas about alternative ontologies of number.

be accounted for. In order for all the specific material arrangements of a phenomena to be accounted in research an assumption of an all knowing, god-like researcher arises. This assumption seems to work against the rest of Barad's account.

In addition to this misgiving, I hesitate to use the term objectivity because it carries with it all the vestiges of science, but perhaps that is part of Barad's project as well, to broaden and open up space in what counts as science. It seems that in qualitative research, the field has moved through phases of tightening and distancing the space between qualitative research and science. At times, qualitative researchers want to be connected to the prestige of science—perhaps then the work will be taken more seriously. Yet, conventionally, the very things that give science power also make tight boxes within which some qualitative researchers do not want to situate ourselves. So, we look to stretch the boundaries of science and what gets to count. I think that if we give up the project of science altogether, we do a disservice to the fields that rely on qualitative research to allow for other knowledges to be heard.

Yet, I am still troubled by the idea of accounting for arrangements, because I wonder where they begin and end. Barad gives the example in her text of the experiment in which the cigar smoke from one of the scientists happened into the experiment and became crucial to the knowledge production. If he had not been smoking a cigar, the discovery would not have been made, so the smoke was part of the knowledge making apparatus, yet it was not designed to be included. It was not an intentional part of the apparatus. It was in excess to it and also crucial to the knowledge production. Researchers bring material–discursive entanglements with them into the enactment of research and cannot know ahead of time (or perhaps even after how they matter).

I find myself again in between. I should clearly state that I am doing this particular kind of science, and it is valid because I take up Barad's objectivity with confidence. Instead, I

question the theory as I take it up. I wonder what boundaries are enacted by this theory, what difference does it make in the knowledge making apparatus. What are the effects of the difference between taking it up versus another theory or another? This between space and hesitancy to settle could be seen as a failure. But I think that there is important and meaningful work to be done on the edges and at the boundaries of theories. How far can this take us? When might it not work? I am interested in the tensions and pulls. Barad argues for the ethical responsibility to stay in the between—that we are not just doing methods or science blindly in a rule bound process-oriented way. Her view of objectivity is relational and rests on a responsibility to the specific material configuration. Barad is working the liminal space of speaking to science and legitimacy and reconfiguring boundaries as to what counts as science. Barad strikes a balance—she is not fixing the meaning or stabilizing concepts, but rather she is creating a space within which we can see how concepts can operate. With some hesitancy, I move forward despite my doubts. I imagine that there might be some cigar smoke somewhere for which I have not accounted, yet I have been responsible to and for the things that I can account.

A New Start… Diffractive Methodology

The above explanation and accounting of both the history of the study and my wrestling with parts of Barad's proposition are part of my accounting of the specific material arrangements of the knowledge making apparatus that includes this dissertation. When I was preparing for my comprehensive exams, I produced a map (see Figure 19) that included as many of the readings that I had done in my studies so far that I could find and the concepts I had been working and thinking with. I felt a sense of responsibility to all of the authors and texts and concepts and materials that had gone into the researcher I was becoming. They mattered for how I would continue to become. I brought the books and materials into the comps meeting. I played the playlist that I am listening to now, that I always listen to when I am writing. I was gesturing

toward the complexity of the intra-action that got me there. I felt a resistance to simplify and close off. I felt that I had to give credit and account for all the influences. And this is an impossible task. I cannot account for all that mattered in my thinking.

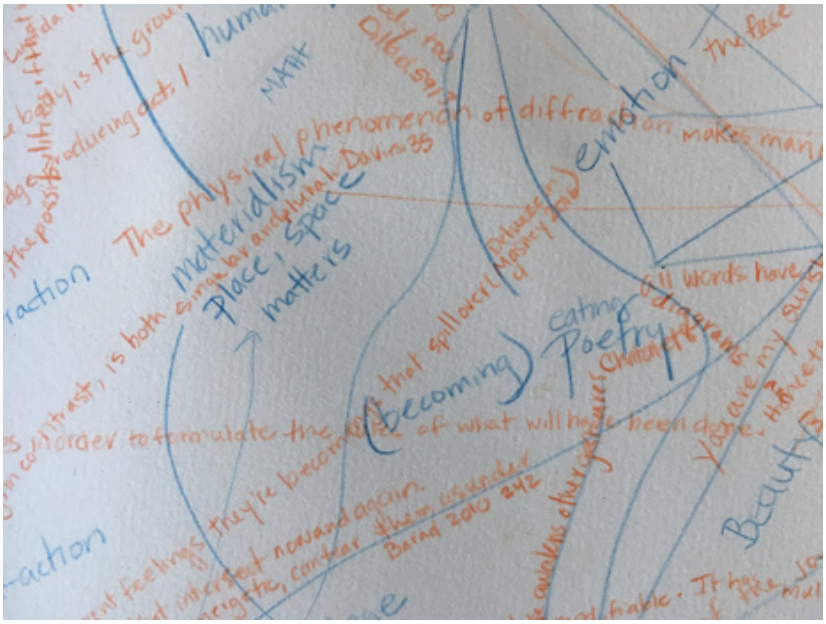

Figure 19. Comprehensive exam production.

And perhaps in trying to account for everything, I am moving toward what looks to us like nothing…. I am moving toward something that seems uncertain and perhaps impossible. I come back to Wanda Pillow's (2003) question that haunted me in my second year of doctoral studies: "How do I do representation knowing I will never get it right?" (p. 176). How do I do objectivity knowing I will never get it right? How do I do research knowing I will enact cuts and leave marks in places that I might not intend? How do I do research with responsibility? What gets left out?

All these questions led me to consider the differences between knowledge making practices and the effects of those differences. Therefore, following Haraway (1997, 2016), Barad (2007), Jackson and Mazzei (2012), and Lenz Taguchi (2012), I work with diffraction—a "narrative, graphic, psychological, spiritual and political technology for making consequential

meanings" (Haraway, 1997, p. 273)—as a way to engage with productions of data to consider what gets left out and as a way to make a difference. The purpose of this study is to see how methods and theories come to matter, in both senses of the word, by constructing a diffractive apparatus that draws attention and attends to the differences produced through various configurations. The goal is not to see which method produces the most true or accurate representation of the middle school mathematics classroom, curriculum, or teachers, but to consider how truths get made.

Data In Intra-action

Data, knowledge, researcher, participant, texts are put into intra-action. They cannot be cleanly separated out from one another as they are always already in co-constituting intra-actions. As Koro-Ljungberg, MacLure, and Ulmer (2018) recently argued, there is an opening in the field of qualitative inquiry to take up and think data differently: to think connections among data and field and researcher, to think data out of time, to think data and place differently, and to think data and anti-data, or what is silent in the data. Data are mobile, co-constituted, material, immanent and situated, though not bound. Data are not neutral. As I argued earlier, data have power in the knowledge making apparatuses, both qualitative and quantitative. How much do you have? Where and how did you get it? Where do you keep it? How do you protect it?

It has been accused of being cooked (Scheurich, 1996, p. 54) or plucked. It is spectral (Nordstrom, 2013); and St. Pierre (1997b) asserts, transgressive in the form of dream data, sensual data, emotional data and responsive data. It glows (MacLure, 2013b) and torments (Bridges-Rhoads & Van Cleave, 2013) and "doesn't sit still" (Koro-Ljungberg, 2015). Data have often been characterized within a binary of being utterly static or almost independently agential.

I think data as somewhere in between—as in intra-action with researcher, participant, students, room, memories, documents, methods, technology. In Figure 20, I gesture toward this

intra-action and like all models and representations, it fails before it starts and can never capture completely. And it makes some things matter that are not always considered as part of data production. Like Barad's (2007) assertions that measurements cannot be considered outside of the specifics of measuring apparatus. Data in an ethico-onto-epistemological frame cannot be considered outside of the specific material arrangements within they are produced. The data are never data on their own as separate and cleanly bounded objects with determinate properties.

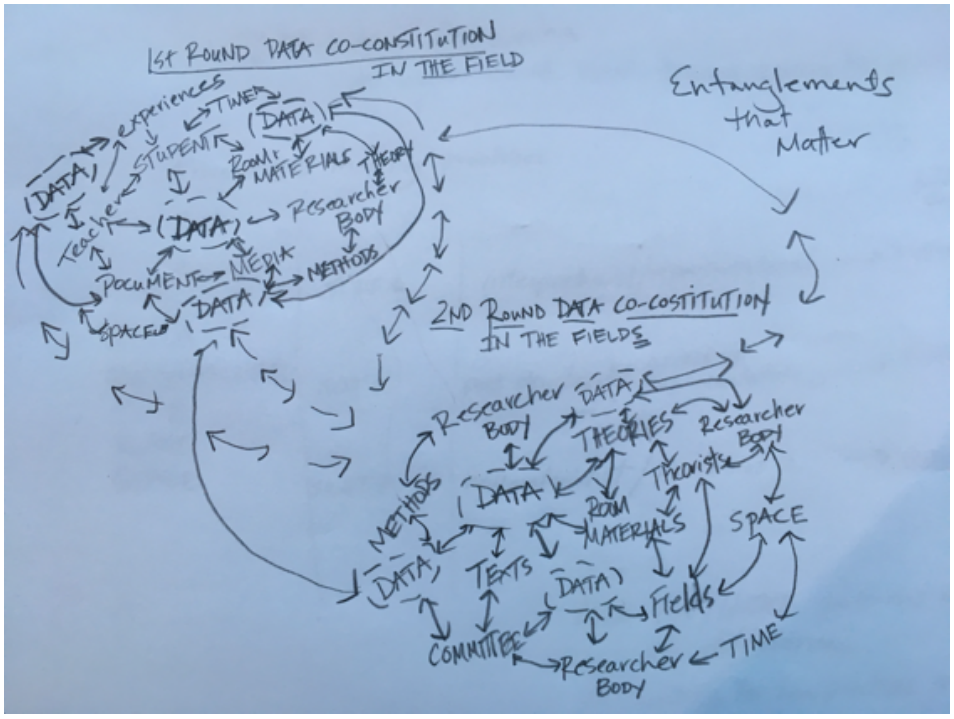

Figure 20. Data productions and entanglements.

The phenomena that I name first round data co-constitution in the field in the diagram above aligns with what educational researchers conventionally name data. These data are the evidence of research in the field: field notes, transcripts, documents. In this diagram, I also account for the materials, bodies, and texts that are in intra-action to produce data. Moreover, I argue that what educational researchers call data are then further co-constituted in the fields and disciplines within a researcher works and thinks. The theories, methods, materials, citations, and

prevalent journals intra-act in how that data in specific material arrangements produce knowledge.

Though this dissertation takes up data as agential (Koro-Ljungberg et al., 2018), I align with Barad's views of agency as distributed in the phenomenon. Therefore, the data only glow in a specific material arrangement, to use MacLure (2013a) often cited example of child-vomit-researcher-teacher-carpet-expectations. The vomiting child does not glow, the field note mentioning the vomit does not glow. The glow is produced in intra-action.

In thinking data/researcher/participant/site as co-emergent and co-constituting, the result is a flattened space of "data + re/overproduction" where "data, researchers, participants, and the world become the same equivalent and indifferent" (Koro-Ljungberg et al., 2018, p. 473). In a flat ontology, agency is distributed and each way of considering data and each iteration matters. This ontological stance (which cannot be separated from ethics and knowing) does not remove responsibility in the production of research. Flattening does not imply sameness or lack of agency, instead it resists taken-for-granted hierarchies and binaries. What this flattening means is that data are not something that are gathered by researchers to represent participants, data are produced in entanglements with participants, researchers, and materials and are ontologically inseparable from them/us.

It is this view of data[71] as co-constituted and connected to the participants and made through intra-action, that gave me a sense of responsibility toward the data from my original

[71] Here, I diffract the ways in which statistics educators discuss data across the ways in which qualitative researchers discuss data. I draw lines of inventive connection that pull these fields into closeness. Wild and Pfannkuch (1999) state, "transnumeration occurs when we find ways of obtaining data (through measurement or classification) that capture meaningful elements of the real system. It pervades all statistical data analysis, occurring every time we change our way of looking at that data in the hope that this will convey new meaning to us" (p. 227), and transnumeration is a way to "re-express the data via transformations and reclassifications looking for new insights" (p. 227). And "we are dealing with complex and sophisticated thinking

study. In this view, using the data that might not have been rich enough or there not have been enough of was necessary. I felt a sense of responsibility to it and its enactment, to what it might become. It was an ethical/political concern for me. I had seen and heard too often of data collected and stored behind keycode password deidentified security only to sit and sit. With just my first transcription, I knew that that one representation was insufficient. I felt a sense of responsibility to get the most out of the data, to wring it out. I had taken the participants' time in the field for interviews. I had been a presence in the room for weeks. I felt that I had barely scratched the surface of what the data could mean and how they could matter, what they could become, what difference they could make.

Thinking Difference with Diffraction

Diffraction is one way to think how the differences in these research/living arrangements come to matter. Diffraction is attuned to "differences that our knowledge-making practices make and the effects they have on the world" (Barad, 2007, p. 72). The goal of the diffractive apparatus described below is not to compare what (method/theory) is the same or different or which (method/theory) is better, but to "carve out what is new through the interference" (Smythe et al., 2017, p. 29). What resonances and amplifications take place when I think across fields and texts that do not normally interact? How might I push against or into the taken for granted? Diffraction and flattening force a different engagement with difference that moves beyond the binary of old/new, good/bad, humanist/posthumanist to attend carefully to the differences these practices make and how they come to matter in educational research. Diffraction is meant to disrupt linear and fixed causalities and to work toward "'more promising interference patterns'

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processes…there is nothing certain or cut-and-dried in applied statistics, the real world is a messy, complicated place" (p. 246).

(Haraway, 1997, 16), both between words and things" (as cited in van der Tuin, 2011, p. 26). The hope is to provoke new thoughts and theories toward inclusion and responsible action.

Diffraction allows for a non-hierarchical methodology that transcends the level of critique and promotes boundary-crossing and trans/disciplinary research. Barad (2014) describes diffractive reading as "affirmative engagement" that seeks to make "new patterns of understanding-becoming" (p. 187). The diffractive apparatus (see Figure 21) constructed in this project was configured with attention to particular arrangements—of data, theory, researcher body, materials, fields—and the meanings, truths, insights, questions, material consequences these arrangements might produce. I conceptualized the apparatus with Barad (2007) and her reading of Bohr's two slit experiment and the diffractive patterns created by the slits. The apparatus in this project, places interpretivist, poststructuralist, and agential realist theoretical frameworks and texts in purposeful entanglement (Marn & Wolgemuth, 2016) with researcher, materials, documents, audio recordings, and field notes. The three-knowledge apparatus come together to make a diffraction pattern to be read/created/invented.

Knowledge Making Apparatus

In this project (and beyond it) there are many overlapping and ongoing apparatus and phenomena, some of which I will call attention to and consider. In this project, according to Barad's agential realist account, I (determined by the agential cut of subject/object, not an actual separate entity) am entangled in the specific material arrangement of dissertation as a knowledge making practice. There are particular and specific material discursive arrangements and agential cuts that are made through the dissertation knowledge making practice. In addition, I am working

on this dissertation as I am embedded in the capitalist and neoliberal knowledge making economy.[72]

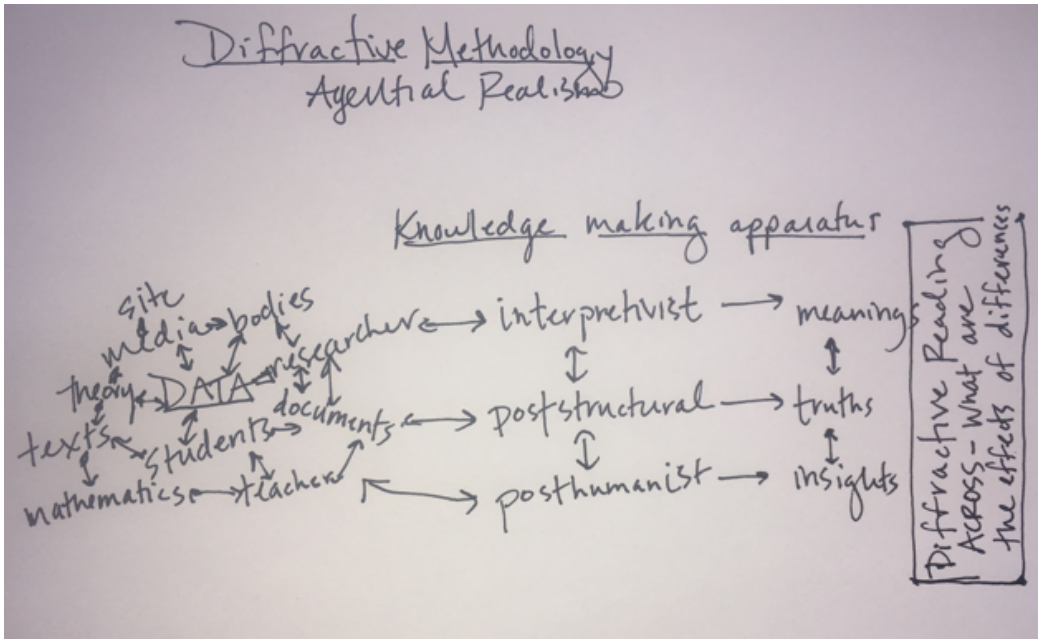

Figure 21. Diffractive methodology.

This diffractive methodology is embedded in a primarily agential realist frame, therefore, the idea of thinking of the three slits as separate is a thought experiment. In this dissertation, I enact cuts between interpretivist, poststructuralist, and posthumanist readings of the data. I hold them momentarily apart to attempt to consider how the differences between the readings might matter. Yet, as Barad (2013) states, "theories are living and breathing reconfigurings of the world" (p. 207). Each reading is a dynamic reconfiguration of the world and is produced in intra-action with particular ways of knowing and fields of research and knowledge. Each reading is a phenomenon with no intrinsic boundaries. The boundaries are enacted, cutting together-apart and leaving marks on researcher, participant, and more than human bodies. In the enactment of this research, I have produced cuts as to what matters and does not matter. I have not attended

[72] See, for example, Brooks et al. (2017); Brown (2015); Davies and Bansel (2010); Davies, Somerville, and Claiborne (2017).

sufficiently in this dissertation (the interpretivist and poststructural accounts) to the raced and gendered bodies in the rooms that work is not here, and it matters and will be attended to in the posthumanist reading that will come after this dissertation but is already in intra-action.

CHAPTER 4: DIFFRACTION PATTERNS

In the previous chapter, I described diffractive methodology and the overall apparatus that is this dissertation. In this chapter, I describe the specific material arrangements of the interpretivist apparatus and the poststructuralist apparatus. As I stated in the previous chapter, I am enacting cuts and making marks on bodies as I separate out these apparatuses within the larger apparatuses of research. In addition, I consider what gets counted in each. Returning briefly to Barad's proposed objectivity, I name and account for the material and discursive conditions of the knowledge making apparatus. Barad's objectivity requires the accounting of the specific material arrangements in knowledge production, and therefore I particularly draw attention to those material arrangements to which I feel especially responsible.[73] I acknowledge that there are many materials that are not being named as counting in the intra-action that also matter.[74]

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[73] As I re-read this, I wonder what it means to feel more responsible to some parts of the arrangement than others. In a conventional view of objectivity, there would be a sense of detachment, and I would need to be equally attentive to all the parts of the research phenomenon. I would need to justify why I emphasize particular parts of the arrangement. I wonder in the agential realist perspective within which I am working whether I can feel more or less responsible to particular parts of participants, and it does not matter if it is allowed or not. It is….

[74] I am still, as I write, in the process of coming to terms with Barad's objectivity and the possibilities of naming the configurations given that there are not determinate boundaries. Yet, as Barad says boundaries are enacted in knowledge making practices, so I acknowledge the parts of the intra-action that I can name. One clear limit this brings to mind in Barad's objectivity is that it relies on the human knower—of course, I cannot think of a knowledge practice that does not. Perhaps, in doing so, I should state that I wrote this footnote on the floor of a hotel bathroom. I sit half-dressed on two pillows my laptop cold on my bare legs. My two children are asleep in the beds less than seven feet from me. My fingers press the keys a little more softly than usual in hopes of not waking them. It is 5:30 in the morning, and we are half way to my mother's house in Florida. I decided to stop at a hotel given that I didn't think I could drive 10 hours by myself. Prior to beginning my Ph.D., I would have driven this route with my then husband. We would have certainly switched drivers and done it in one day. These material changes in my life and the material reality of the places where I have written matter in what gets said and how it is said.

Cuts are enacted within the research phenomenon, subject/object distinctions are produced, and yet the cuts are not clean. Theory and method and data leak out and overflow and exceed categories, as I notice this messiness, I have tried to resist cleaning up these leaks and overflowings. Instead, I point to the excesses because I think these excesses matter. I point out my own gasps. By noticing what is taken for granted and what is excess, I can begin to see the previously enacted cuts. I am doing research knowing I can never get it right and knowing that it matters. My response-ability to the research process is an ongoing responsibility[75] to the worlds intra-active, lively, and burgeoning becoming.

After outlining the interpretivist and poststructuralist knowledge making apparatuses, I consider the differences they make and how those differences matter. The two iterations create a diffraction pattern, as they overlap, are in excess, slow and speed in relation. I want to foreground here that I am not attempting through iteration to make a clearer picture of these classrooms, these teachers, or the curriculum. Instead, I iterate to see what difference difference makes.[76]

Again, I cannot note all of the places my writings have come from, but I provide this example to illustrate both that it matters, and it is impossible to account for in full.

[75] I use response-ability (Barad, 2012) when considering my ability and attention in response as a part of the research phenomena. I use responsibility as a gesture toward what I owe to others in relation to them, which is premised on a moral view of relations where there are particular agreed upon rules to follow in how we should behave. If I were to write this sentence again, I would use response-ability in both places for theoretical reasons; however, I think that I still often operate in my life and research in a space of "shoulds." I should have asked her another question. I should have said thank you. I should have waited longer for her response. I should be sitting down taking notes. I should not take up so much space.

[76] Thinking difference with the methodology of this dissertation also aligns with the ways in which data is taken up and considered in statistics education. There is a focus on variability and context in statistics education and also an understanding that there is not an absolute answer to a statistical question. The answer depends on the specific material arrangements of the context and the statistical model.

Interpretivist[77] Knowledge Making Apparatus, Specific Material Arrangements

In the spring semester of my fourth year of doctoral coursework, after I had conducted the original study but before I had written or defended my prospectus, I was asked to teach an elementary mathematics methods course on data and analysis for undergraduate students. In response to the request, I enrolled in the graduate-level version of the course for that same semester as I had not taught the course before and was not familiar with the research or literature. As a part of the expectations for the graduate-level course, I was required to conduct a literature review in the area of data or statistics for elementary to middle grade students. After reading just a few articles, I was struck by how this field aligned with my previous research in a middle grades mathematics enrichment class, the initial study in this research. Reading literature in statistics education, thinking in a field in which I had not intended to play, I rethought my study and began to ask different questions about what that research might mean and do. The data that I had collected and analyzed began to shift as I thought it within the space and context of statistical thinking. In addition, the ways in which statistics educators discussed data resonated with the ways qualitative researchers I was reading thought data.

During this time, two of my professors were engaged in the tenure process, and I was approaching the job market. My embeddedness in the phenomena of the neoliberal academic system disciplined me toward clear research trajectories and clear positioning as a scholar. I felt

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[77] I originally called this reading conventional prior to reengaging with the paradigm chart (Stinson & Bullock, 2015) in Chapter 2. In naming I enact a cut, and here the cuts are important. This reading leans toward the critical, so I am in the liminal between interpretivist and critical paradigms within the interpretivist-constructivist and social-turn moments respectively. Stinson and Bullock (2012), in fact, consider the moments and paradigms that they name "as distinct yet overlapping and simultaneously operating" and as messy and containing gaps (p. 43). Stinson and Bullock (2015) describe the interpretivist-constructivist moment as a move from researching to predict to researching to understand, although the ways in which researchers seek to understand within the moment may differ. They list several paradigms within each moment. Furthermore, they propose that researchers in the social-turn moment, often "oscillate" between the critique and deconstruct paradigms (p. 9).

the need to legitimize my work and connect more clearly to the field of mathematics education. The connections I could make with statistics education literature and mathematics education were appealing to me in this regard. Framing mathematics education through statistics education literature would make this dissertation legible to a mathematics education audience.[78] In addition, I found that there was a call for attention in research to lines of connection between equity and statistical literacy in statistics education.

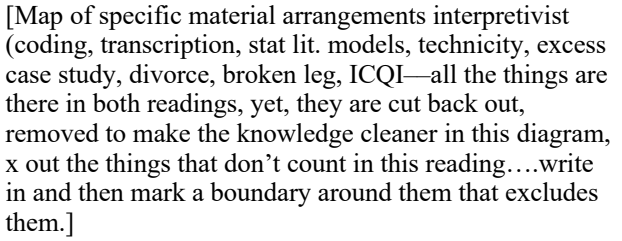

Figure 22. Map of specific material arrangements interpretivist reading.

The Phenomena of Statistical Thinking in Statistics Education Research

The field of statistics education research has been growing as a field along with mathematics education research. Both fields are beholden to the disciplines of mathematics and statistics. Statistics has gained a place in the mathematics curriculum in the United States nationally beginning with data and analysis standards in the early elementary grades (see, e.g., NCTM, 2000). Statistics educators argue that the dispositions necessary for statistical thinking take years to develop; and therefore, the early introduction of this type of thinking is important (Engel, 2017; Wild et al., 2017). Too often, however, statistics education in schools does not develop these dispositions and instead favors the skills of reading tables and constructing graphs

[78] Looking back from here/now, it seems that attaching my research to statistics education made me less legible to some mathematics education researchers. It was a field crossing that they were uncomfortable with. However, for my ongoing thinking/being/researching, I find this crossing and making kin with statistics education research joyful and productive.

using clean and prescribed data sets. Therefore, statistics educators have worked to develop models of statistical thinking that attend to the types of thinking and dispositions needed to engage in the complex work of statistics (Wild & Pfannkuch, 1999). This study contributes to both the early engagement of students in statistical thinking and dispositions, the calls for attention to equity that statistical literacy might answer, and the need to do statistics within real and messy contexts. Therefore, taking up the data from the initial study while engaging with literature from statistics education research felt like a responsible thing to do. There was a gap in the field with which this study could be aligned. There was a need for this type of work. Therefore, in this knowledge making apparatus, I consider the ways in which the data from the initial study comes into intra-action with the recommendations in the GAISE report (2005) and Wild and Pfannkuch's (1999) model of statistical thinking.

Wild and Pfannkuch (1999) proposed a model of statistical thinking that includes four dimensions: Dispositions, Types of thinking, Interrogative cycle, Investigative cycle (see Figures 23-26).

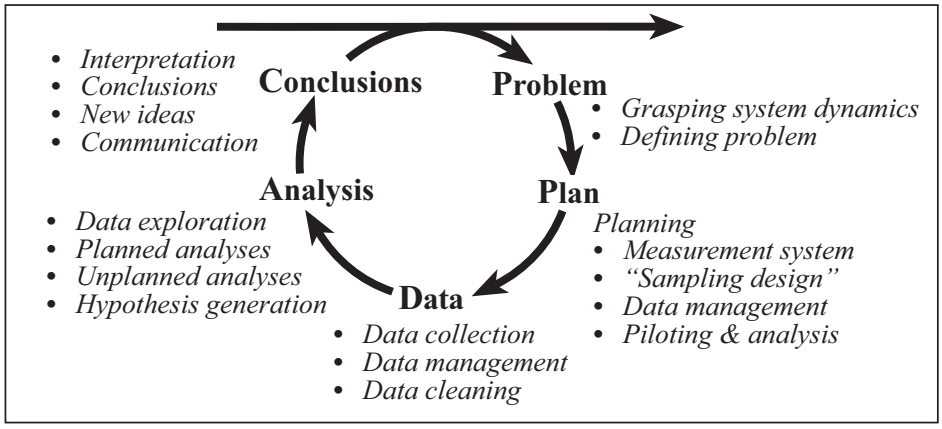

Figure 23. Dimension 1: The Investigative Cycle. (Wild & Pfannkuch, 1999, p. 226)

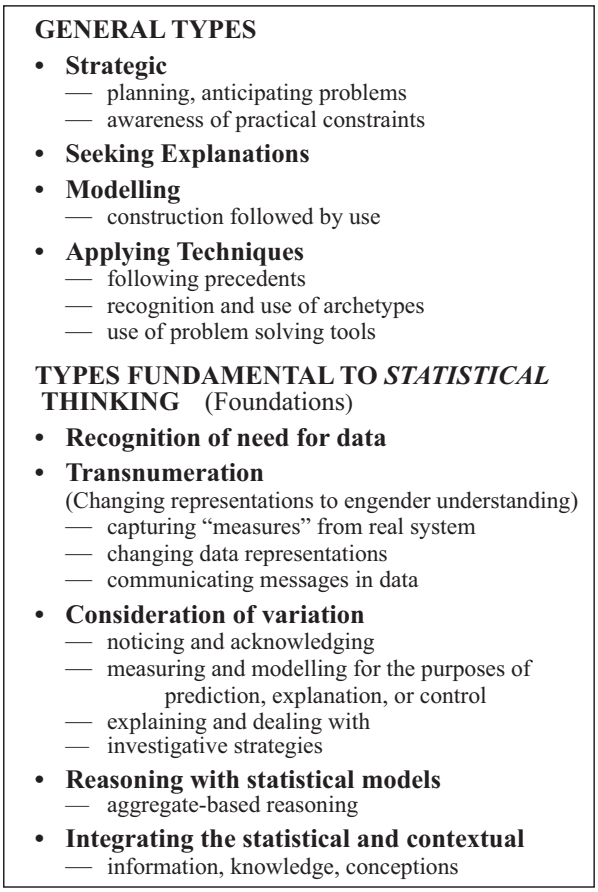

Figure 24. Dimension 2: Types of Thinking. (Wild & Pfannkuch, 1999, p. 226)

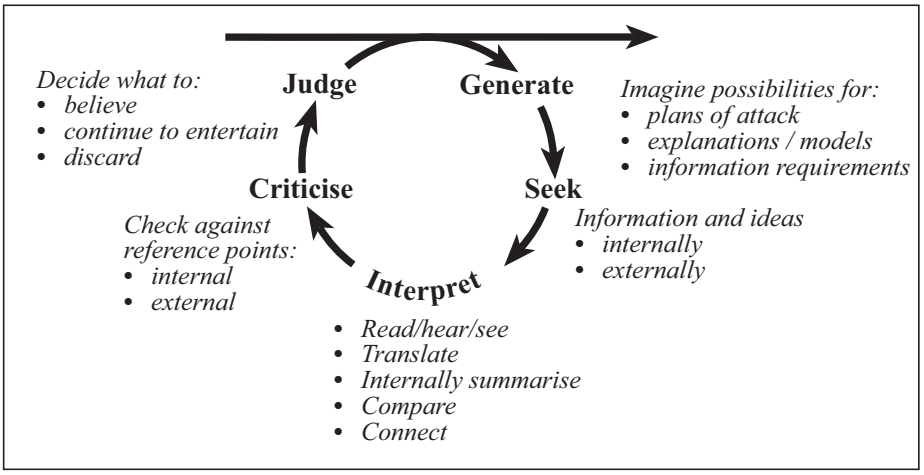

Figure 25. Dimension 3: The Interrogative Cycle. (Wild & Pfannkuch, 1999, p. 226)

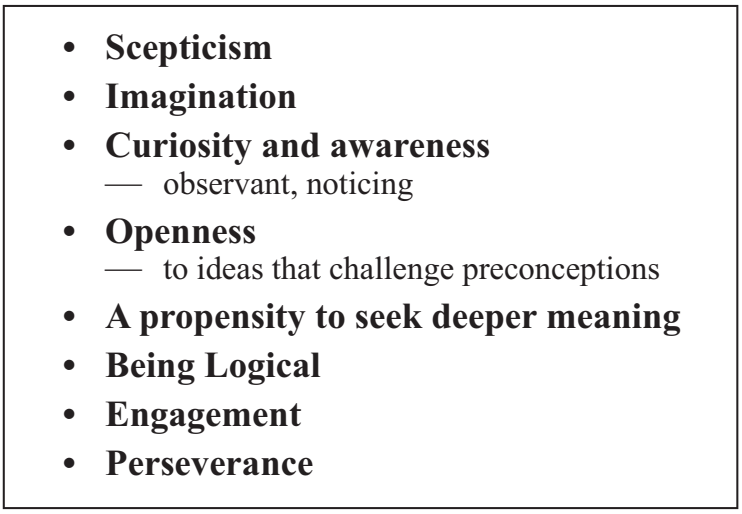

Figure 26. Dimension 4: Dispositions. (Wild & Pfannkuch, 1999, p. 226)

I found this model useful because it accounted for both the ways that students might think and the dispositions that students would need to think in these ways.[79] I appreciate the attention to thinking and dispositions as this framing accounts for how long it might take for these behaviors to develop and that the dimensions might overlap.

The purpose of this knowledge making apparatus is to consider ways that the curriculum design, pedagogical decisions, and student work samples aligned to models of statistical thinking proposed by Wild and Pfannkuch (1999) and the GAISE (Franklin et al., 2007) recommendations. Given the lack of studies in the United States of teachers in middle grades classrooms teaching for statistical thinking, this project is an important contribution to the field.

[79] Here, I am attempting to write this as I would for publication given this frame. Doing so seems jarring. There is tension for me in writing this research up this way. Stating that there are dispositions that are separate from the types of thinking, each of which can be developed grates against Barad's ethico-onto-epistemology and my beliefs about teaching and learning. Even referring to beliefs has become problematic, so how do I/might I/would I communicate to an audience that relates to this language, that may well change their thinking in response to my study if it is framed appropriately. How do the cuts I am enacting in this writing/telling matter for students and schools?

Methods

In this qualitative case study, I conducted classroom observations during the 10-week course. I wrote field notes, including dialogue, lesson structure, and media displayed. In addition, I conducted a total of five in-depth interviews (between 1–2 hours in length) with the participants, two middle grades teachers, Ayesha and Elisabeth—one with each prior and at the conclusion of the course and one additional photo elicitation interview with one participant.

I audio recorded each of the interviews and transcribed each recording. I analyzed the data from the interviews, field notes, and classroom documents. In my first cycle coding of the data, I set up what Saldaña (2016) might refer to as a procedural coding method, in that it was prescriptive (p. 174). I constructed nodes for each of area within Wild and Pfannkuch's (1999) dimensions of statistical thinking (see Figures 23-26) reread the transcripts, field notes, and student documents, to consider whether there was evidence of statistical thinking in the data using NVivo 12 (see Figure 27).

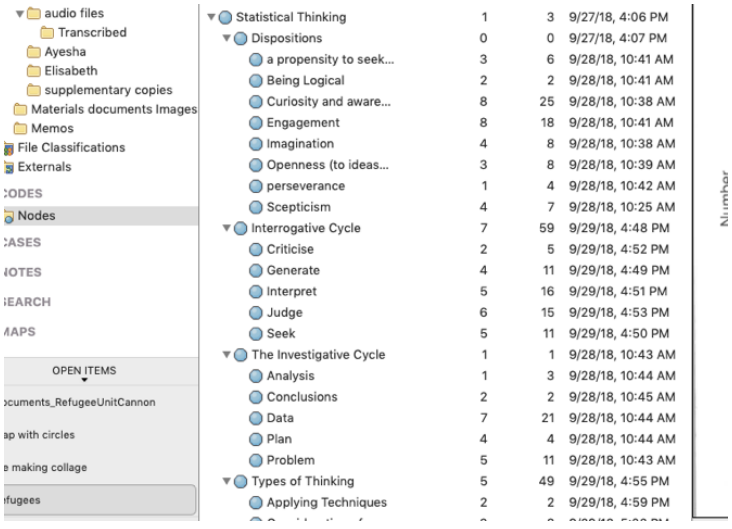

Figure 27. Screenshot of NVivo nodes.

In addition, to coding for the dimensions of statistical thinking, I also considered the course goals and the course evaluation given by the teachers. The evaluation was developed and administered by the teachers as a part of their normal practice of obtaining feedback from students and was given to me with all of the other documents for the course. I was not involved in the construction of the document. The teachers surveyed the students at the end of the course. They asked the students to complete a handwritten response on the one-page front and back document that included reflection on the course goals. On this document, the teachers listed the following as the goals of the Current Events Math course:

1. Students will explore the numbers behind current events.
2. Students will draw conclusions from the data
3. Students will use statistics to make inferences about the meaning of these events.
4. Students will explore the importance of numbers when assessing the magnitude or meaning of an event.
5. Students will find ratios and percents.
6. Students will create and use equations.
7. Students will read graphs, including line graphs, bar, graphs and pie charts.
8. Students will create graphs, including line graphs, bar, graphs and pie charts.

Analysis[80]

In the following sections, I present the results of the alignment between Wild and Pfannkuch's (1999) dimensions of statistical thinking and the data from interviews, classroom observations, and documents. In aligning the data, there were clear connections between the teachers' curriculum design and pedagogy and the dispositions of statistical thinking that could be drawn.

Curriculum design and statistical thinking cycles. Studying the documents for the units from the 2015-16 school year and field notes from classroom observation, I found that the

[80] This paragraph was one of the hardest for me to write in this dissertation. Even in trying to write in interpretivist paradigm, I hedged by talking about connections that could be drawn rather than saying something like, the data from this study illustrate that….

curriculum aligned with Wild and Pfannkuch's (1999) interrogative cycle. The teachers were not familiar with Wild and Pfannkuch's model of statistical thinking and did not design the course to attend to statistical ideas or dispositions.[81] For each unit, the teachers asked the students to listen for and read information about the event outside of class. In addition, the teachers gathered images, articles, and video clips about the topic. As they moved along in the units, the teachers refined this process of reflection and created worksheets that the students used to record their noticings, thoughts, and ideas (see Appendix B–E for student samples). The questions used in the worksheets are summarized in Figure 28.

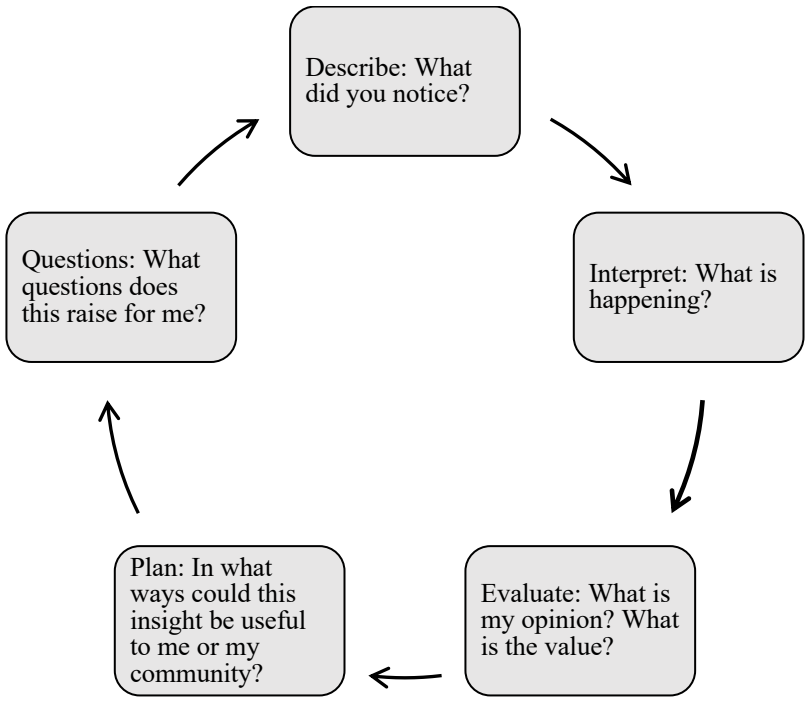

Figure 28. Curricular cycle from course.

[81] Writing in this frame it seemed important to know that the teachers just happened to align with the model that it was not planned, that I did not give them the cycle ahead of time. In fact, I had not even read the research on statistics education when I started outlining the cycle they were using. And again, the standards speak to these cycles, so even if they would not have cited Wild and Pfannkuch (1999), they may have been consciously or unconsciously pulling on a cycle of statistical thinking. The alignment could be diffracted or explained in many ways, happenstance, serendipity, validation, proof—I am noticing the cut I am making.

The cycle that the teachers used in the first few days within each unit (see Figure 28). held aspects of Wild and Pfannkuch's (1999) interrogative cycle. I align the cycles in the table below and then detail each part of the cycle.

Table 1
Comparison of Two Interrogative Cycles

Wild and Pfannkuch (1999) Interrogative Cycle	Current Events Math Interrogative Cycle
Generate: Imagine possibilities for: plans of attack, explanations/models/information requirements Seek: Information and ideas: internally, externally	Describe: What did you notice?
Interpret: Read/hear/see, translate, internally summarise,[82] compare, connect	Interpret: What is happening?
Criticise: Check against reference points: internal, external	Evaluate: What is my opinion? What is the value?
Decide what to-believe, continue to entertain, discard	Evaluate: What is my opinion? What is the value?

Describe. For example, the process began with the introduction of the topic with media (photos, videos, articles):

> So, the first thing we do in this class with any issue is we do research. We start off by asking, "What do you already know about this?" and then kids get ... I provide them with some background information, just some reading, either an article or something from the internet that tells us about whatever the situation is.
> (Elisabeth, 9-20-16)

The worksheet read, "Describe: What did you notice? (No judgement)." This statement relates to the generate and seek portions of Wild and Pfannkuch's (1999) cycle. They describe generation as "imagining and brainstorming to generate possibilities, as an individual or in a group" (p. 232). In the seek stage, Wild and Pfannkuch described seeking or recalling information as both internal (I know something about this from personal experience or memories), and external (obtaining information and ideas form sources outside the individual or team). Internal and

[82] When pulling directly from Wild and Pfannkuch's (1999), I use their spellings.

external seeking as described by Wild and Pfannkuch were especially noticeable in the unit where student's explored Traumatic Brain Injuries (TBI) in the National Football League (NFL). The teachers purposefully put a student football player in each group. In groups, the football players and students who had not played football brought data from internal and external sources for discussion. During discussion, and in response to the prompt about connections the students noticed to other learning, students said things like:

> My godbrother's friend died in the middle of a football field.
>
> I have sprained my wrist.
>
> My dad has been hurt in football.

These statements could be classified as internally sourced. In addition, the students drew on external sources, such as:

> A while back there was a podcast on how safe should football helmets be. They talked on how if the helmets are too safe that players might use their helmets as weapons. This could be related to a movie called "Concussion" that is about football players becoming insecure in their later lives due to concussions.

Wild and Pfannkuch also include reading relevant literature and collecting data as part of the seeking process. In the Current Events Math course, the students read relevant literature that they found on their own, as well as articles brought by the teachers.

Interpret. In the next phase of the course, the students interpreted the media and data. The teachers provided prompts in this section: "Interpret: What is happening? Explain what I see and find connections." This phase aligns with Wild and Pfannkuch's (1999) description that students should process, internally summarize, compare, and connect the results of their seeking. In making connections, Wild and Pfannkuch expected students to interconnect new ideas and information with existing mental models and "enlarge[e] our mental models to encompass these interrelationships" (p. 232). They identified a problem in this phase in which students would make one connection and then rush to judgement rather than trying "to make multiple

connections or going through the criticism phase" (p. 232). In field observations and in student work, I noticed students rush to judgement. Both the teachers in the course used rounds, where students shared their noticings in succession one at a time around the circle in order, to develop[83] the students' ability to notice when they were making judgements and become attuned to the difference between a judgment and a noticing. They also assured that students were encouraged to pay attention to several points in the data, by having students share their noticings aloud. The teachers did not privilege one response over another in these rounds. (I provide an example of this pedagogical move later in this chapter.)

Evaluate. Following the interpretation phase, in the next phase of the teacher's curricular cycle, they asked the students to evaluate with the prompt: "Evaluate: What is my opinion about this? or What is the value of this? Why do I think this? (Make judgments that are clearly connected to observations I have made)." This phase relates to the criticize phase in Wild and Pfannkuch's (1999) interrogative cycle. Considering the football unit as an example, students in this phase evaluated the knowledge they had sought and interpreted in relation to both internal and external reference points. For example, students stated:

> I don't think people should play this game if they are going to get hurt.
>
> There should be a study on how many people are getting hurt and where then increasing the padding in that area.
>
> It is bad that people are getting this hurt.
>
> I think that after all the articles I've read that there should be a solution to this.

[83] I am noticing my ease now in writing in this way in separating out and making statements of what happened in the classroom and what it meant. I wonder if I am a traitor to my theory in being able to do this or is this an ethical/political move to consider how research might be taken up and by whom and how it might matter in and for schools. Yet, how am I to know how it might matter or not in particular formats and which is better? How am I to be responsible for what this research becomes or what it might do if it is taken up at all?

Plan. After evaluating, in the next phase of the curricular cycle developed by the teachers, they prompted the students with the following statement: "Plan: In what ways could this insight be useful to me in classes, at home, in my life, in general?" This phase relates to Wild and Pfannkuch's (1999) judge phase in which they suggested that students decide "what to keep, what we discard or ignore, what we continue to tentatively entertain, what we now believe" (pp. 232–233). In their view, this is the point in which statisticians judge the reliability of ideas, practicality of plans, rightness of encapsulation, and conformance with context. They suggest that the result of the interrogative process is a "distilling and encapsulating of both ideas and information" (p. 233). Furthermore, they suggest that internal interrogative cycles help us "extract essence from inputs, discarding distractions and detail along the way" (p. 233).

Aside from predicting based on the raw numbers and doing the calculations, the teachers asked the students to consider the risk associated with traumatic brain injury, prompting, "What percent would you use to rank the risk of traumatic brain injury? Why?" These questions functioned to bring the students' attention to the multiple and varied choices made to represent risk in the media using numbers. Furthermore, this activity encouraged students to consider that the way risk is calculated could change the perception of which position is riskiest.

Question. Elisabeth and Ayesha's final phase in the opening segment of each unit was for students to brainstorm questions that they had related to the topic and the data at hand thus far. They prompted the students: "Questions: What questions this raises for me? List as many as possible." Some examples of student responses from the football unit include:

Why do players not have padding that can take hits?

Is the NFL gonna make the sport safer?

Why would people keep playing?

What would happen with no helmets?

Will these people be ok? How can we help?

Does football cause more injuries than other sports?

This part of the process functioned for Ayesha and Elisabeth as a way to gauge interest to various parts of the topic and to consider what to explore in the next phase. It was also a way for students to make sense of the topic and decide what mattered to them about it.

Criticize. After developing questions about a topic, the class moved to consider data related to the current event that aligned with the criticize phase in Wild and Pfannkuch's (1999) model. For example, in the TBI in NFL unit, the teachers presented the students with a table of statistics from the NFL including the number of cases of TBI by position and the number of game positions. The students then calculated the percentage of incidence of TBI and the percentage of injury per times on the field and connected this second calculation to the risk for the player in that position of TBI (see Figure 29).

Data Table: 1994-2001 NFL research of mild traumatic brain injuries

Offensive/ Defensive	Position	No. of case	total cases	% **incidence** of TBI	no. of game positions	% of injury per times on the field: **Risk**
Offence	Quarterback	62	784	% 7.9086	3826	% 1.62049
Offence	Running Back	69	784	% 8.80102	7652	% .90172
Offence	Wide Receiver	94	790	% 11.89873	7652	% 1.22843
Defense	Linebacker	52	788	% 6.59898	11478	% .45304
Defense	Secondary	143	786	% 18.19338	15304	% .93439
Defense	Defensive Line	67	788	% 8.50888	15304	% .43779
Special Team	Kick Unit	131	789	% 16.603	38260	% .34239

Figure 29. NFL data table.

During the criticize phase, students checked for internal and external consistency, weighed the data against other data sources and context knowledge and considered the reasonableness of the data in relation to their questions. Students also moved into the criticize phase in the Ebola unit, in which the students researched past outbreaks and the available statistics to compare them, and the Michael Brown unit, in which the students looked up the arrest and police stop records from the county and considered the data by race. In the next section, I discuss specific pedagogical moves that teachers used through the phases that were related to the development of statistical literacy.

Pedagogical moves. Aside from the curricular cycle that structured the overall course of each unit, within units, both Ayesha and Elisabeth used rounds in their classrooms as a pedagogical tool. In addition to creating equity of voice in that it made sure all students got to speak, noticing rounds highlighted the variability of thoughts and data in the media that is critical to developing statistical thinking. The rounds also built engagement with the topic and curiosity that relates to Wild and Pfannkuch's (1999) dispositions that I expand on in the next section.

As an example, the teacher would display an image or a movie for the class on the smart board. The students would take notes of what they noticed in the image or video. Sometimes they would watch the video twice to give the students a chance to engage deeply with the topic. After sufficient exposure to the media, the teacher would ask the students to state out loud what they noticed in the media. Below is an example from one classroom observation; each line represents a new student speaking in turn:

1. I notice that Brent Boyd was asked how many words he could think of that started with B and he could only say 5–6.
2. I noticed that Brent Boyd played football and got hit too hard too many times and got TBI.
3. I noticed that concussions can make a part of your brain dead.
4. The same thing (T. Go ahead and say it) I noticed that concussions can make a part of your brain dead.
5. **Teacher:** Remember noticing is specific things we observe that are objective

6. I noticed players hit in the head multiple times in the video
7. I noticed that he only played in NFL 6 years and people play longer imagine how many play 10 years or more
8. I noticed in the first video clips (note: teacher is calling students by name) of people hit in the head by other players helmet fell off and a chunk of a helmet fell off
9. **Teacher:** I noticed that too
10. A couple of players killed themselves because of CTE
11. I noticed he lives with this son
12. His symptoms lasted longer than a regular concussion
13. **Teacher:** How many concussions did he have?
14. Over 200
15. There's only 365 days in a year
16. That's 30 concussions a year.

In line five, the teacher offers feedback to keep the students focused on what they could observe in the image. After the noticing round, students would move to assumption rounds or questioning rounds. For example, the following is a sample questioning round from the TBI in the NFL unit:

Teacher: What questions arise for you? We have 3 mins left… So, we're listening

Student responses:

1. Would it be possible to study healthy brains and make a microchip to fix it like with eyes?
2. Would he go to law school instead of the NFL if he had it to do over?
3. What part of the brain is most effected?
4. How many suffer from ETC now?
5. How many of each type of player suffers or will be diagnosed?
6. Are any of the plans for players 14 and under to get help?
7. Can you get CTE without a concussion?

Teacher: What I love about your questions is that they are very specific.

The time for reflection was a pedagogical tool that encouraged students to notice and respond to their own biases. By first stating what they actually saw in a photograph and then, writing about the assumptions the photo raised for them, they were often confronted with unsubstantiated biases. This practice was an effective lead-in to consider the bias inherent in statistics presented in the media. As the questions that students asked in the assumption and questioning rounds illustrate, in addition to building statistical thinking dispositions like engagement and curiosity, these rounds also promoted the outcomes of statistical thinking as outlined by Wild and

Pfannkuch (1999). For example, the student questions above demonstrated the recognition of the need for data, the consideration of variation, and the integration of the statistical and contextual.

Omnipresence of variability. By using messy data from real world contexts, the teachers asked the students to confront the omnipresence of variability in data. When asked what the incidence rate tells about a player position, a student responded, "some are more dangerous than other positions and that some are getting far more interaction with other players." Franklin and colleagues (2007) outline three types of variability: natural, induced, and measurement. The food unit and the NFL unit were apt examples of natural variability given that the types of foods a person eats in a day varies from person to person and some positions get hit more than others due to the natural flow of the game. The Ebola unit introduced students to measurement variability as students explored the various ways that scientists might have measured and calculated the worst outbreak. Finally, the students explored induced variation when they considered the protests in Ferguson and that the incidents of black or brown drivers getting arrested was higher due to the fact that more cars with black and brown drivers were pulled over.

Statistical thinking dispositions. Although there were clear phases in their curricular cycle, Elisabeth and Ayesha also focused on developing what they called criticality in the students. Elisabeth explains about the opening phase:

> They do reading, and then they report out to each other and we try to debunk misconceptions in that very first part. There were initially some ... The misconceptions that were just in the media or out there, and looking at the actual reporting helped us debunk some of those situations.

As Elisabeth notes, criticality occurred in the describe phase, not just in the evaluate phase. The dispositions, as a separate dimension of statistical thinking in Wild and Pfannkuch's (1999) model work across the phases of the cycles.

Wild and Pfannkuch (1999) named eight dispositions necessary for statistical thinking: skepticism, imagination, curiosity and awareness (observant, noticing), openness (to ideas that

challenge preconceptions), a propensity to seek deeper meaning, being logical, engagement, and perseverance. The coding frequencies for each disposition and the number of sources are displayed in Table 2.

Table 2
Statistical Thinking Dispositions as Evidenced by Data from Current Event Math Course

Disposition	Number of Sources	Number of Codes	As described by Wild and Pfannkuch (1999)
Skepticism	4	7	"a tendency to be constantly on the lookout for logical and factual flaws when receiving new ideas and information" (p. 234)
Imagination	4	8	"hard to overemphasize the importance of imagination to statistical thinking" (p. 234)
Curiosity and Awareness	8	25	"questions are more important than answers noticing variation and wondering why engagement–intensely interested–heightened sensitivity and awareness develops towards information on the peripheries of our experience that might be related to the problem" (p. 233)
Openness	3	8	"helps us register and consider new ideas and information that conflict with our own assumptions" (p. 234)
Propensity to seek deeper meaning	3	6	"not simply taking things at face value and being prepared to dig a little deeper" (p. 234)
Engagement	8	18	"becoming intensely interested in a problem or area" (p. 233) "engagement intensifies each of the 'dispositional' elements" (p. 234)
Perseverance	1	4	"perseverance is self-evident" (p. 234)
Being logical	1	1	"the ability to detect when one idea follows from another and when it does not" (p. 234) "to be useful skepticism must be supported by an ability to reason from assumptions or information to implications that can be checked against data" (p. 234)

In the following sections, I give examples of how several of the dispositions named by Wild and Pfannkuch (1999) could be aligned with the data from the Current Events Math course.

Skepticism. Wild and Pfannkuch (1999) describe skepticism as "a tendency to be constantly on the lookout for logical and factual flaws when receiving new ideas and information" (p. 234). Ayesha described an incident with one student. She said that he was the only one interested in where the table presented to the class came from. He said, "Where did you get this? What is the citation for this graph?" Elisabeth described another time when she stated that an infographic was from *The New York Times*. She implied that then it could be trusted, yet a student remarked that you cannot always trust the newspaper.

Imagination. In the Food Unit, the teachers shared pictures of people from around the world with the amount and types of food they would eat pictured in front of them. As they scrolled through the images, the students tried to imagine why different people might need different amounts and types of foods. Of the woman with AIDS who ate 900 calories, a student said, "maybe that's all she could eat, or maybe she makes herself eat that much because she has children." Another student said: "Maybe she is vegetarian, and she has to get all of her calories from vegetables, she may not eat meat, or she might. She has to travel a lot on unpaved streets and hilly streets." Although this may not seem crucial to statistical thinking, Wild and Pfannkuch (1999) emphasized the importance of imagination, and the teachers of the course encouraged it through their acceptance of all answers and interpretations. At least in the early phases of the cycle, the teachers did not discourage any responses as being outside of bounds. Imagination in the course took the form of the students putting themselves in someone else's shoes and taking multiple views or perspectives on a problem.

Curiosity and awareness (observant, noticing). In Wild and Pfannkuch's (1999) descriptions of statistical thinking, questions are more important than answers. They posit that

curiosity and awareness lead students to notice and wonder about variation. They state, "heightened sensitivity and awareness develops toward information on the peripheries of our experience that might be related to the problem" (p. 233). This disposition was built in the noticing and questioning rounds that the teachers used in each unit that were detailed above. In classroom observations, throughout the units the teachers modeled curiosity, they wondered aloud about students' responses: "What makes you think that?" and about data, "I wonder where they got that number." In addition, the teachers chose topics that they thought would be of interest to the students.

Openness (to ideas that challenge preconceptions). As in the previous disposition, openness to ideas that challenge preconceptions was also developed in the noticing rounds. The separating out of rounds meant for naming things that could be seen and things that were inferred from the images and videos honed the students' ability to differentiate between the two. The teachers also consistently accepted all ideas within a round as long as it fit the requirements of the round (noticing or inferring). More explicitly, Elisabeth, when asked what she hoped the students would get out of the course, stated, that she wanted the students to become "people who are conscious of what is happening around them and are willing to speak up, are willing to try to get more and willing to change if, not changing the world, changing their environment."

A propensity to seek deeper meaning. Wild and Pfannkuch (1999) describe this disposition as "not simply taking things at face value and being prepared to dig a little deeper" (p. 234). In speaking with Ayesha, she communicated her desire for students in the course:

> You know I hope that that is what they get out of it. Looking at me as their teacher is learning that like it is ok and if they hear something in the media then they will be like there must be a different side of the story as well or what are the numbers to help you more being conscious.

In the curricular cycle they used, Ayesha and Elisabeth always began by asking the students what they already knew about the topic or what they thought a representation meant to build curiosity

and engagement. This tactic over time built students' interest in finding out what was behind an image, representation, number, or symbol. In the photo elicitation interview with Ayesha, she brought a map of the Mediterranean Sea with red circles scattered across it of varying sizes (see Figure 30).

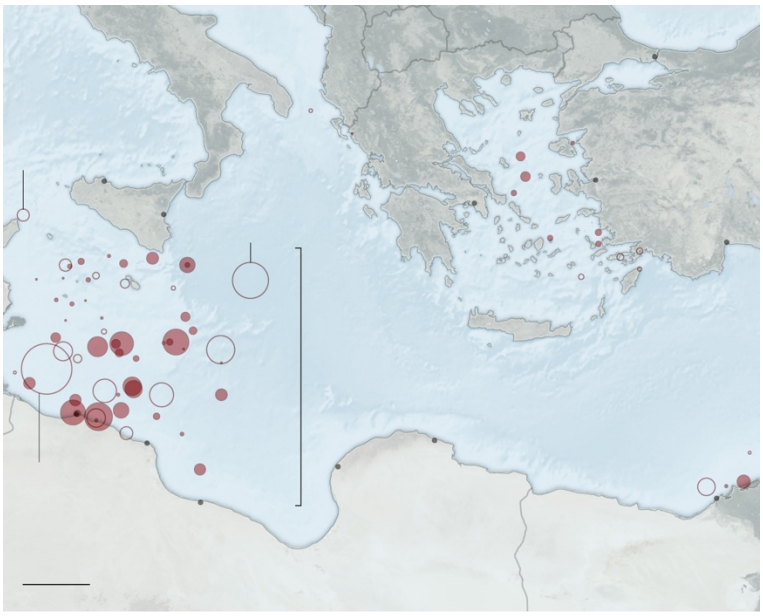

Figure 30. Image Ayesha brought to interview.

See https://www.nytimes.com/interactive/2015/04/20/world/europe/surge-in-refugees-crossing-the-mediterranean-sea-maps.html?_r=0

She told how in the European Refugee Crisis unit, they had shown the students this image and asked them to imagine what the circles might represent. The students were allowed a round of predictions. They were surprised to learn that the circles represented incidents of refugees who were lost or died at sea and were sized by the number dead or missing. The act of having to predict meaning and then have such an impactful meaning revealed struck the students. Ayesha described in the interview that it was like a light bulb went off for the students in that they began to understand the power of representation both in what could be shown and what gets hidden in representation.

Engagement. Engagement, like several other dispositions, can be tied back to the rounds that Ayesha and Elisabeth used at the beginning of each unit. In addition to the pedagogy of the round, the media that they found to show the students was interesting, relatable, and provocative. I wrote in my field notes during the opening of the NFL unit:

> The player is testifying in congress, we see him unable to remember, to complete sentences, to express a thought. The film ends with the player describing how he now lives with his 24-year-old firefighter son. He mentions this as a reversal. This brings tears hovering behind my eyes. I breathe. Ayesha asks students to write on their reflection sheet. They begin writing intently. I hear pencils clicking. She hands me a reflection sheet. There is sustained and silent writing for 5 minutes without extra noise or coughing or shuffling—rare in a classroom. Finally, at the end, there is tapping foot.

At the end of the class period, I stayed to speak with Ayesha and confessed that I had found the session to be intense. Ayesha stated, "I am glad they're all connected to it. I didn't think football would be the thing. They all care. I am surprised. I don't care about football." I asked if she thought the caring was really about the football. I did not write down her response,[84] I am not sure if she responded. Looking back, I think the engagement was somewhat about the topics, but it was also about the seriousness and integrity with which the teachers approached each topic and the students' responses to the media.

Course survey. In considering the impact of this course on the students, I end with the results of the course survey. The teachers asked students to reflect on the goals that they thought the teacher met in the class and that they, the students, personally met in the class. The results of this survey are reported in Table 3. The students were instructed to put a check by a goal if it was met by the teacher and a star if met by the student. The goals of the Current Events Math course were listed as follows:

1. Students will explore the numbers behind current events.

[84] Here the marks of the poststructuralist reading that I have been going back and forth between comes through. This tone and style of writing, the use of the extensive quotation seems more suited to that reading, yet the admission that the response was not written done is more interpretivist.

2. Students will draw conclusions from the data
3. Students will use statistics to make inferences about the meaning of these events.
4. Students will explore the importance of numbers when assessing the magnitude or meaning of an event.
5. Students will find ratios and percents.
6. Students will create and use equations.
7. Students will read graphs, including line graphs, bar, graphs and pie charts.
8. Students will create graphs, including line graphs, bar, graphs and pie charts.

Table 3
Current Event Math Goals and Student Evaluation of Goals

Goal	1	2	3	4	5	6	7	8
Only Teacher	44%	25%	44%	44%	38%	25%	13%	38%
Student & Teacher	44%	50%	44%	31%	38%	44%	50%	44%
Only Student	13%	25%	6%	19%	25%	31%	25%	19%
Student & Teacher + Only Student	67%	75%	50%	50%	63%	75%	75%	53%

The results of the survey show that at least 50% of the students thought that they met each of the goals. Goals 2, drawing conclusions from data, goal 6, creating and using equations, and goal 7, reading graphs had the highest percentage (75%) of students who thought that they had met the goal. Goals 1, exploring numbers behind current events (67%) and 5, finding ratios and percents (63%) were the next highest. In addition to the questions about the goals of the course, the survey included an open question asking what students thought they got out of the course. They stated the following:

- It gave me a way to connect other subjects to math
- I know now there are things bigger than myself
- I was not the best in math, but I learned a lot
- It made me better in math
- I learned new things
- You can be aware of things that are happening in our community

- I think it helped grow my math skills more
- It gave me a challenge
- I learned scientific notation
- It was useful because it helped a lot in MST
- I realized other things going on in the world

Interval

gears turning metal on metal grinding
perhaps some oil
make it more efficient
less noisy and noticeable
be a good machine
do your work better
measure
notice
take note
capture
generalization
generalize
erase difference
group
sort
categorize as they slide down the belt
good this way
bad that
the discards
the leftovers
the nos
no
no
no
forget numbers
measure nothing
notice
feel
look and respond
smile
wonder, ask
seek wisdoms
complicate
complication
complexity
boundless intricacy
yes
yes
yes

– Fall 2015

As, I move between these readings. I provide some space between them to hold them apart even though they are always already stitched together through the ever-expanding footnotes. I have created a binary between interpretivist and poststructuralist readings, I am feeling around for the borders of the theories and noticing where they exceed and leak into each other. Marks have been made on my researcher body in moving back and forth between these versions.

"Permanent marks …[are] left on bodies" (Barad, 2007, p. 119), not just my researcher body. Each time I work with and through the data they are arranged within a new phenomenon of which I am a part, and it carries the marks of previous arrangements. A death comes sweeping back to me. A smile in the collage gestures to the original photograph and the moment it attempted to capture.

Nvivo coding created grooves that the data fit in, and a screenshot attested to its reliability and validity. And the program and the particular confines of the screen and windows and arrangements of codes are actors in the apparatus, the technology makes marks. The data are "locked in painful categories and trapped on the wrong side of vicious boundaries" (St. Pierre, 1997b, p. 176).

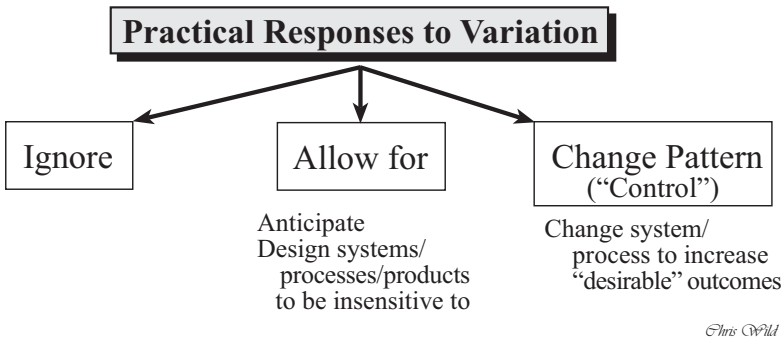

Figure 31. Responses to variation (Wild & Pfannkuch, 1999, p. 236)

The chart in Figure 31, created by statistics educators seems helpful to think with. How am I responding to these data, to these differences in theories?

When I read transcripts on the floor listening to the audio recordings with colored pencils marking up the lines, there are also limits that the particular material arrangements place on the knowledge making apparatus.

I am not sure that I will get there in this dissertation, but I want to work across the binary between these readings to see the light in the dark and the dark in the light and to make inventive lines of connection across. I want to think coding as making kin or maybe coding as technicity (Manning, 2016).

"Furthermore, as we have seen, there are actually no sharp edges visually either: it is a well-recognized fact of physical objects that if one looks closely at an 'edge,' what one sees is not a sharp boundary between light and dark, but rather a series of light and dark bands—that is, a diffraction pattern" (Barad, 2007, p. 156).

Poststructuralist[85] Knowledge Making Apparatus

The poststructuralist knowledge making apparatus was constructed before I knew it. I did not think of it as a knowledge making apparatus at the time. I was enrolled in Qualitative Research Methods II and Poststructural Inquiry in the fall semester of that year and Qualitative Research Methods III and Foucault and Feminism in the spring semester. Through my qualitative research classes, I was conducting interviews, transcribing, doing observations with the teachers and students in the Current Events Math classrooms. I started writing up the study; as I wrote, I focused in on the idea of truths. This focus came from my readings in postructuralism and the specific material arrangement of my life at the time. In addition to truths, for similar reasons, I was curious about what responsibility and ethics should or could look like. To whom am I responsible and in what ways?

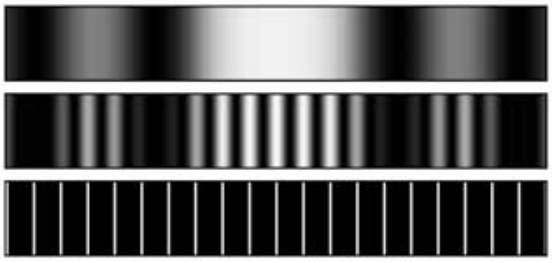

Figure 32. Diffraction pattern.

[85] Stinson and Bullock (2015) describe the sociopolitical-turn moment as characterized by researchers who "explore the wider social and political picture of mathematics education…[signaling] a shift toward 'theoretical [and methodological] perspectives that see knowledge, power, and identity as interwoven and arising from (and constituted within) social discourses'(Gutiérrez, 2013, p. 40)" (p. 9). As within the previous reading in this moment, researchers often oscillate between the critique and deconstruct paradigms. In this reading paradigms under the emancipate heading (e.g., critical, social justice mathematics) and the deconstruct heading (e.g., postmodern, poststructural) are in operation, although for the ease of communication and because this is how I was thinking this reading at the time, I call this section poststructuralist. In thinking of the poststructuralist, I follow Kuby (2017) in thinking of this paradigm as one that helped me "focus on *what is produced* unlike an interpretivist paradigm that focuses on *what an interaction means*" (p. 5).

In the spring, I also engaged in a directed reading centered around subjectivity. In addition, I went to Japan in March of that year and engaged with readings that questioned tradition and marriage. I visited Hiroshima and spent 10 days away from my husband and my children. I questioned every taken-for-granted assumption in my life. I wondered what was true, whom I should be responsible to, how to be good in this framework that seemed to leave a vast grey between very slim slices of black and white (see Figure 32). I produced the poststructuralist reading of the data during this specific material configuration. It is no wonder I ended up interested in diffraction patterns.

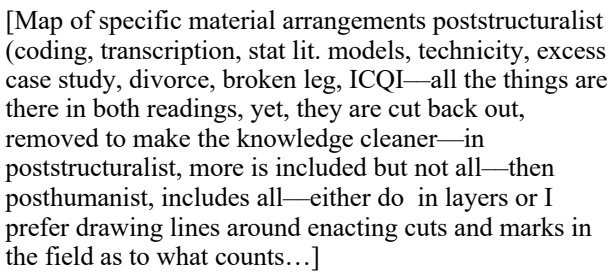

Figure 33. Map of specific material arrangements poststructuralist reading.

The Phenomena of Uncertainty, Truth, and Ethics in Mathematics Education Research

According to Ernest (2012) "the primary objects of study in mathematics education are human beings and their activities and relationships" (p. 12). Mathematics is a social construction and thus, the participants in its construction are ethically responsibility for its effects. Ethics and mathematics are not often thought together, yet I agree with Ernest (2012) that "ethics is the first philosophy of mathematics education" (p. 13). Ernest follows Levinas' conception of ethics as "infinite responsibility to the other" (p. 13). Mathematics, then, should be considered in relation to the social, material, and political world from which it is constructed and with attention to the

ways this positions the "other." Mathematics is often given privilege as both true and unbiased. Changing the conception of what mathematics is and what it can do changes the subjectivities that are available to students within the mathematics classroom.

Within the field of ethics, Neyland (2004) asserts, "the primary ethical domain is not monotonous, regular or predictable; it is shot through with uncertainty and contradiction and cannot avoid ambiguity" (p. 61). Thus, it is particularly important that ambiguity is recognized within the field of mathematics education. Neyland refers to mathematics education as "paradigm case subject" (p. 62) in the postmodern ethical agenda because "it is the curriculum subject that can be used to make the strongest case against the project of modernity in education more generally" (p.62). Thus, uncertainty and ethics and mathematics education go hand and hand. Ernest (2016) promotes conceptualizing mathematics as an uncertain science. Certainty in mathematics is "not something natural, independent of culture… but it is something that derives from many years of engagement with the subject and associated cultural presuppositions" (p. 388). If certainty in mathematics can be produced through social interactions and school mathematics, then a stance that values uncertainty can also be produced.

A stance of uncertainty would be impacted by the practices and pedagogies of the mathematics classroom, not only the content. Boaler and Greeno (2000) argue, "the *practices* of learning mathematics define the knowledge that is produced" (p. 172). Considering multiple perspectives and exploring the effects of looking at and solving a problem from each perspective could also allow students to see themselves and mathematics differently. Mathematics does not always lead to one "truth" and mathematicians do not always have to be certain. When each perspective presents a different truth about the situation, the students see that mathematics is a flexible tool, not a series of procedures to be followed. This perspective aligns with Neyland's

(2004) idea of mathematics as crucial in the postmodern ethical agenda in that it allows more and different students to engage in these subject positions.

Similarly, Hottinger (2016) argues, "we need to tell different stories about mathematics to expand our cultural understanding of who can engage in mathematics" (p. 13). Math is typically presented as linear, absolute, and unquestionable. When thought in this way, students believe that they should be certain of their mathematical knowledge and view the mathematics presented in the news as truth. Boaler and Greeno (2000) state, "the figured worlds of many mathematics classrooms… are unusually narrow and ritualistic, leading able students to reject the discipline at a sensitive stage of their identity development" (p. 171). These narrow and ritualized spaces resist the emergence of new stories or new subjectivities.

The purpose of this reading is to consider the practices that teachers use to produce a space for uncertainty in a middle grades mathematics classroom. In addition, I trace the various truths that were produced in the classroom and how those truths relate to ethics. I take up multiple and overlapping layers of ethics: ethics of the researcher in the field, ethics of the teacher toward her students, ethics of the citizen in a community, and ethics of representation in the media. The teachers hoped that through the course the students in the course might be more distinguishing and critical readers of mathematical content and the social context within which it is deployed.

Methods

This study took place in middle school classrooms of two mathematics teachers that I knew and admired. I do not expect that the practices that took place in these classrooms (which were measurably different from each other) could be or should be replicated without concern for context into middle school classrooms across the country. Rather, this study raises questions and

might prompt mathematics educators to question *their* practices and the context of those practices.

Data collection. In transitioning from a teacher to a researcher and in taking up new theories, I began to see what I had not been seeing in the classroom before. The classroom observations and interviews left me entangled with the concepts and questions of truth and representation. I felt the persistent tug of positivism at my sleeve. Aren't numbers, data, facts materialized manipulations of the cognitive processes involved in measurement? Numbers are "arrested 'moments' of measurement captured through technical decisions" (adapted from Knowles, 2006, p. 512). The research questions I had entered the classroom with became questions about the process of research. How do I use mathematics/research to produce truths? How do I deconstruct "truths" created through mathematics/research that are dangerous or destructive?

This reading includes data from teacher interviews, classroom observations/field notes, photo elicitation, researcher journal, and student and teacher created documents. In considering these documents, I view them as co-constructed by the authors, participants, school, and students. These documents, from transcribed interviews to student journal entries, do not have single authors or sites of production. In interviews, the teachers were asked directly about how they thought their view on mathematics influenced their teaching of the course and their views on mathematics and its relationship to truth. I also asked the teachers to describe how they thought students had changed in their relationship to mathematics over the 10 weeks of the course. Data also encompassed field notes, classroom observations, and blinded student work from all units of study. In addition, I attended a unit planning session with both teachers and took notes on the conversation. I looked at student work from the beginning of the course to the end

and also considered multiple student work samples across individual units. I viewed the collected data as co-constructed by the participants, school, students, and me.

In coding my field notes, I used what might be described by Saldaña (2016) as eclectic coding that combined hypothesis coding (i.e., types of truth) and concept coding. I also asked questions of the data and myself in the margins. Although I did not take a technical view on coding and rigorously apply a procedure, I did find that the process of reading through and writing with the data was productive in helping me to consider the study. I noticed themes that I would not have seen without another intentional pass through the field notes. I ended up writing a lot and asking questions about the ethics of research. I noticed the places that I tried to show care for my participants and where they showed care for me. This rereading highlighted the importance of relationships in research and also my tendency to (over) apologize and a need to be careful in my relational ethics (Ellis, 2007). The entangled process from start to finish of designing the study, asking participants to be interviewed, observing, reviewing documents, and writing up field notes and memos cannot possibly result in one truth about this experience. It cannot be represented simply or succinctly. The data also cannot be separated from me or the participants as we have both had our hands in them (me more than them perhaps).

As I worked with the data, I noticed a disconnect between the data produced through the interviews (the teachers and me talking about the course) and the documents and field observations. When I coded my initial interviews, the theme of truth came up a lot; I began to think about different ways that truths are constructed. In the interviews, the teachers and I talked about truths that were constructed and put forward by the media. We also discussed ways that the teachers used math with the students to deconstruct particular truths or to help students to begin to understand a truth, such as racial profiling in their study of the Michael Brown's murder in Ferguson. In classroom observations, I noticed how different students and the same students at

different times, pulled on numbers/statistics or personal experience or empathy to assert a particular truth.

Truth production in research. When I read Alice Fulton's poem "Cascade Experiment," I was drawn to two lines in particular:

> Because truths we don't suspect have a hard time
> making themselves felt
>
> Nothing will unfold for us unless we move toward what
> looks to us like nothing: faith is a cascade. (as cited in Barad, 2007, pp. 397–398)

I thought about this research. I wondered what I was looking for from it. What was I moving toward? I came to these two classrooms because I thought I knew something about what I would find there, and I knew about the people in them. I knew the school and the culture. People warned me, that's dangerous—don't work at your own school. Yet, I did. I thought I would find something that I already knew was there. In the visual methods process I undertook, I was confronted with what I thought was nothing. I am in the process of moving toward.

> Knees crack
> I crouch over text
> Trying to make her more visible
> Then they come
> Leaking out
> Pushing their way through
> One by one
> The unseen
> The unsung
> Searched
> Sliced
> Stuck
> Yet I don't see
> They are paper tigers
> crouching in tall grass
> Slips of paper under the corner of the rug
> forgotten.
> Make, create, don't feel, do.
> I cut them all without regard.

In both the photo elicitation and the collage that I made with the printed version of my first imperfect transcription, I was struck by what came forward that I had not seen. The conversation with Ayesha went beyond what I think I would have gotten through an interview. Harper (2002) contends:

> I believe photo elicitation mines deeper shafts into a different part of human consciousness than do words-alone interviews. It is partly due to how remembering is enlarged by photographs and partly due to the particular quality of the photograph itself. Photographs appear to capture the impossible: a person gone; an event past. That extraordinary sense of seeming to retrieve something that has disappeared belongs alone to the photograph, and it leads to deep and interesting talk. (p. 23)

The images were like a third person in the room that created a comforting distance between her and me. She talked easily with them there about difficult and personal topics. After our conversation she said, "that was hard." I asked her if the conversation was helpful or hurtful. She said it was hard but good and that we talked about things she never talked about and that "helps me to know what I think about things." Perhaps the conversation and photographs broke through her frame, or what Harper (2002) described as "breaking the frame is [the idea] that photographs may lead an individual to a new view of their social existence. It is also possible to use images as bridges between worlds that are more culturally distinct" (p. 21). I asked her to bring an image that meant something to her. She chose two graphics from the class. One was a map of the Mediterranean from which she had removed all text and labels. The other was a bar graph indicating the numbers of refugees in ten different countries. At first, I thought that these visuals would not lead to a substantial conversation, but it quickly became clear that these images held deep significance for her. Even though it was not a photograph of something in her past, having that as a reference allowed her to focus on something outside the two of us. She seemed less self-conscious in the discussion. The material presence of the images provided "a cautioning awareness that should help us overcome the inevitable power differentials of subject and researcher" (Harper, 2000, p. 728).

In trying to open up and reconsider transcription and representation, I made a collage with the transcription of my first interview (see Figure 34). I began by taping the transcript together end-to-end and laying it out in my bedroom, which is also where the interview took place. I then played the audio recording of the interview and went back through and underlined and circled existing text and added another layer of text and questions in response to reading/hearing the interview. In this process, I noted particularly a play between the rational, reason, math and numbers on the one hand; and joy, emotion, and the affective on the other. There was a resonance throughout that math and numbers lead to truth or truths, that math helps you to find truth, to interpret correctly, to see what is real. This reminded me of Harper's (2000) "fictional perceptional reality":

> Now it is no longer what we see (or hear and feel) that is real, as in the case of a science based on unchallenged claims to represent the world. Rather, we choose to immerse ourselves in a fictional perceptional reality—that is, a perceptual world that is the result of our imagination and machine. (p. 718)

The interplay between truth and seeing led me to bring images into the collage. I then went back to my computer and conducted Google image searches for the main topics raised in the interview, refugees, Michael Brown, New Horizons, the factory explosion and air pollution in China, abortion, Ebola, and gender violence in gaming. For each topic, I did a search and printed the first page of images for that search. I then went through and added this layer to the transcript. The Google images represent the visual discourse that surround the topics and part of what people "know" about this topic. Or what they "see" when the think about these topics? I struggled with the initial transcription and the technological impact or resonance in the transcription, then I printed it and put my hands on it. But I went back to technology for each layer, letting Google privilege certain images on the collage. I thought of this as a way to represent the most seen images, those most present in the discourse, or was I just putting back in front of myself and my audience the same truths that we had already seen? In adding the photos

to the transcript and my writing the images/photos literally cover up the text of the transcription, as they also add another layer and uncover. As I laid the images and text on the page, I reread the text around them, both my own and the transcription, and this new collection brought new meanings.

Figure 34. Composing the transcript/collage.

This composing comes near to Mitchell's description of representation as something assembled over time out of fragments. The aim is to "make materially visible the structure of representation as a trace of temporality and exchange, the fragments as mementos, as 'presents' re-presented in the ongoing process of assemblage, of stitching in and tearing out" (Mitchell, as cited in Radley, Hodgetts, & Cullen, 2005, p. 278).

The stitching—or taping, in my case (see Figure 35) —became less careful as I went on through the 20 pages of transcript. I began to rush, to desire completion, and taped photos onto the transcript without seeing them or their context. I became aware of this haphazardness and paused and thought about how I am not seeing these photos at all. I am placing images of dead

people on the page as representative of them and not seeing them with any emotion. I am rationalizing. I am trying to finish.

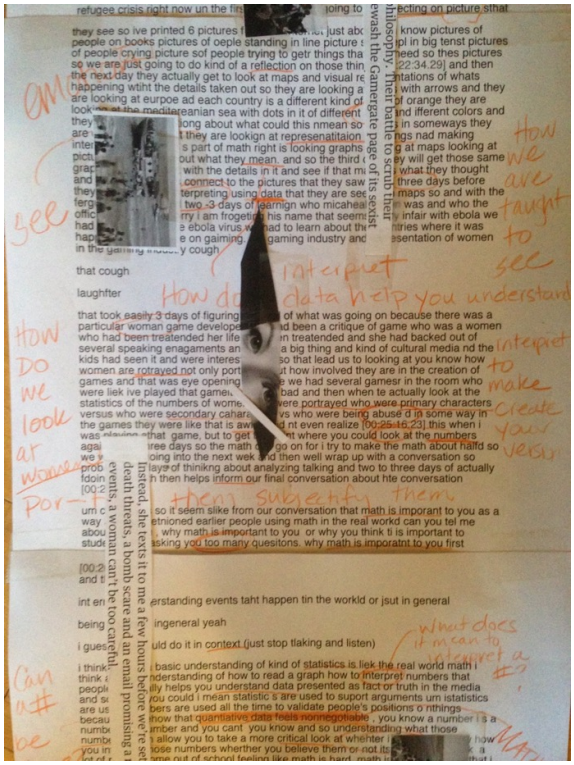

Figure 35. Collage/transcript detail.

This process pushed me to consider my research question and to analyze and reconceptualize what might be data for this project differently. I was intrigued by the ideas around math, numbers, data, truth, interpretation, and morality that I might not have "seen" were it not for this process. Knowles (2006) described seeing and its connection to photography and differentiated photography as "a materialized manipulation of the (equally manipulated) cognitive processes involved in seeing. Photographs are arrested 'moments' of seeing captured through technical decisions" (p. 512). Aren't numbers, data, facts materialized manipulations of the cognitive processes involved in measurement? Numbers are arrested "moments" of measurement captured through technical decisions. How do we use mathematics to produce

truths? How do we deconstruct truths created through mathematics that are dangerous or destructive?

Analysis

As I considered the making of truths in research processes, I attended to the truths produced through the Current Events Math course. I first describe the curriculum and context of the course. I then elaborate on versions of truth that operated in both the course's content and on the outskirts.

Curriculum design. At the beginning of the course, the teachers and students brainstormed relevant and timely topics in the news. The students brought ideas in and all ideas for study were listed on the board. From there, the students voted on two or three topics by putting a check mark next to it on the board. The class then collectively decided on topics to pursue and the order that they would be pursued with direction and input from the teacher. For a list of topics and the connected mathematical skills (see Table 4).

The teachers expressed a desire to help students in getting "behind the numbers" and developing criticality and responsibility. Their main goal with the course was to expose students to mathematics as it related to current events and their lives, particularly around issues of justice.

Table 4
Current Event Math – Current Events and Mathematical Topics

2014–2015	2015–2016
• Ebola (measures of center) • Michael Brown and Protests in Ferguson, Missouri (rates and ratios) • Gender Imbalance and Violence toward Women in the Gaming Industry Marriage Equality Act	• New Horizons Mission (scientific notation) • European Refugee Crisis (rates, graphing, %) • TBI in the NFL (%, probability) • Sugar in Food (variability) • Rand Paul $1M/min • Air Pollution in China (%, rates)

For each unit, the teachers asked the students to listen for and read information about the event outside of class. In addition, the teachers gathered images, articles, and video clips about the topic. Elisabeth described the process:

> Out of any 5 days, it would be really nice to have 2 of those days at least be math. When you're doing current events math, it's really important you understand the current event. Rather than lecture the kids about it, I would much rather have them learn about it themselves, and so we often do a jigsaw where one day, I pull a bunch of pieces of information. They each, like in small groups or individuals, read bits and then they come back, and they report the next day.
>
> They create a poster, or they create a notes page, or they create a presentation, something. In that second, and sometimes third day, we are just finding out about the current event, like more in depth than just the three lines that I gave you on day one when we started. After that, we get into the math of it and sometimes ... Like for example, we're headed into the European refugee crisis right now. The first 2 days are going to be reflecting on pictures that they see. I've printed six pictures from the internet just about pictures of people on boats, pictures of people standing in line, pictures of people in big tents, pictures of people crying, pictures of people trying to get the things they need. We're just going to do a reflection on those things and then the next day, they actually get to look at maps and visual representations of what's happening with the details taken out. They're looking at maps with arrows, they're looking at Europe and each country is a different color or orange. They're looking at the Mediterranean Sea with dots in it, of different sizes and different colors, and they're just speculating about what could this mean. I guess, in some ways, they're doing math and they're looking at representations of things and making interpretations, so that's part of looking at graphs, looking at maps, looking at pictures and figuring out what they mean.
>
> The third day, they will get those same maps and graphs but with the details in it and see if that matches what they thought, and then how those things connect to the pictures that they saw. It's 3 days before they ever get to really ... 2 days before they actually get to interpreting; using data that they're seeing in maps.

As they moved along in the units, the teachers refined this process of reflection and created worksheets that the students used to record their noticings, thoughts, and ideas (see Appendix B–E for samples). The questions used in the worksheets are summarized in Figure 36.

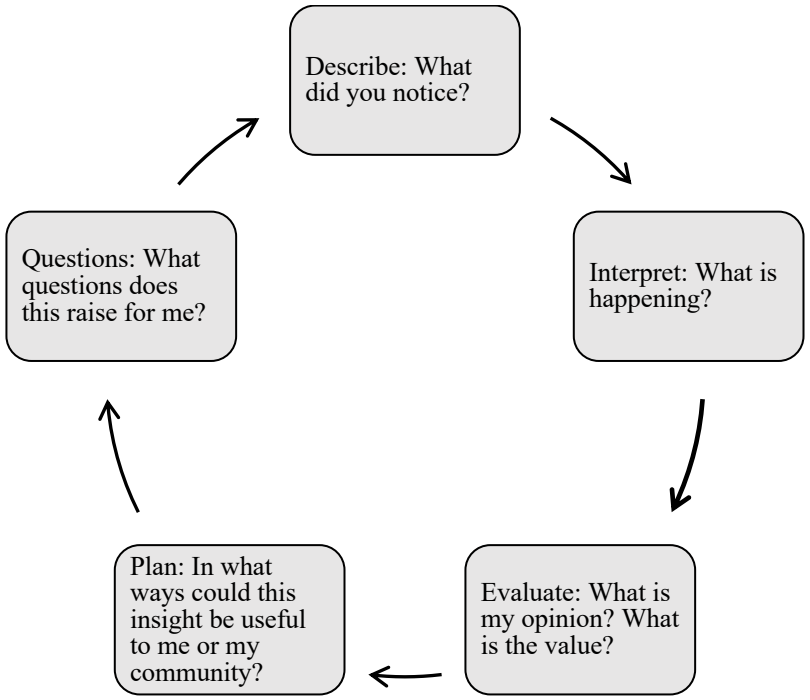

Figure 36. Ayesha and Elisabeth's curricular cycle.

Truth and experience. Throughout the course, students often drew on their own experiences to justify a claim. In one unit, the teachers arranged the class to accentuate the reliance on truth from experience. In the unit of TBI in the NFL, the teachers organized each small table groups to include one football player. In the unit, the students collected and analyzed data and statistics about the likelihood of concussion or TBI for particular positions. As the students did their analysis, there was tension between the truth presented by the numbers and the truth(s) brought by the group members founded in their experiences on the football field. In a group that included a student who had played cornerback, when the students calculated how likely it was for a cornerback, for example, to incur and concussion, that student was particularly attentive to the data that represented his position. Regardless of the percentage, if he had been hit hard in his time playing football, the student might contest. The students were asked to wrestle with the idea of truth as—running full speed ahead, hearing your breath in your own ears and

feeling its moisture on your face, and then a bone crunching hit from the side and the sudden scent of grass and mud—or as, cornerbacks suffered 10% of the total concussions reported by the NFL in 2013. The students then had to consider, which is more valid, reliable, and believable? Which one counts? How might these truths influence the students' belief in a number?

Truth, bias, and prejudice. Truth(s) arose out of biases and numbers and new truths were created through numbers to undo prejudice. As the class researched the shooting of Michael Brown in Ferguson and the subsequent protests, mathematics helped them to understand the injustices that had been occurring there. Elisabeth stated in her first interview:

> Looking at the race issue in Ferguson, Michigan became a question of math actually. So why do some people feel like it's not fair or not equal? What we could do with Ferguson was to look at the population numbers and the arrest records. We could look at records of police stopping individuals and keep track of those statistics by race over time. As we looked at these numbers and converted them into a percent, because that was the math we were looking at. When we equalize numbers, we're not just looking at the number of people, but we are looking at a number that is kind of stabilized by percent by having the same denominator. The kids were able to say, "Oh that's not, that doesn't seem fair." If 70% of the people you know, if they only represent 30% of the community but 70% are stopped, they begin to see that there is inequality there. So, then you can go back to the original question of why are there riots, and kids can say, "Oh because it really doesn't feel fair because out of 10 people, 7 of your friends have been stopped by the police, but if you're White only 3 of your friends have been stropped by the police. As a Black person, you're like, "Hey everybody gets stopped by the police," and as a White person, you're like, "Really, do we get stopped by the police?" So that piece, that particular instance was getting at the core of why is there rioting aside from the emotional piece there was math behind it. There was math that could help kids understand how somebody who wasn't like them might feel.

When I spoke to Ayesha about what she hoped students would take away from the course, she also spoke about truth from bias, but from a different perspective:

> **Susan:** What are you hoping that students will take away from the course?
>
> **Ayesha:** A sense of responsibility.
>
> **Susan:** To whom or to what?
>
> **Ayesha:** To those around them
>
> **Susan:** What would that look like?

> **Ayesha:** People who are conscious of what is happening around them and are willing to speak up, are willing to try to get more and willing to change if, not changing the world, changing their environment. Or if you are at the airport and you have someone who is very different that comes and sits next to you being comfortable in that situation.
>
> **Susan:** Um huh
>
> **Ayesha:** You know I hope that that is what they get out of it. Looking at me as their teacher is learning that it is ok and if they hear something in the media then they will be like there must be a different side of the story as well or what are the numbers to help you be more conscious.

In these instances, the data, ratios and statistics, helped the students to see injustices and to recognize prejudices. Alternatively, data are used in ways that increase bias and prejudice.

Multiple or conflicting truths. The students and teachers studied the Ebola outbreak in the spring of 2014. The class researched the outbreak and asked, what was the worst outbreak in history? To answer this question, they had to wrestle with questions such as: *What is worst? And worst to whom or for whom? Does worst mean the highest total number of deaths, or the highest percentages of deaths per infection, or the percentage of the total population that was infected and died during the outbreak?* Elisabeth talked about these multiple or conflicting truths—the idea that truth can be used by anyone to pursue any agenda:

> I worry sometimes that the idea of social conscious or justice can be used by all people to pursue any agenda. I can say there's uncertainty, and I can say everyone can find their own truth, but the bottom line is the math can help us differentiate between exaggeration and what's really there, so we talk again about the rounding situation looking at politicians and what they say. If we look at the real, the numbers we can actually know, this and then the media or politics can change them or turn them and look at them from another direction, and say no they mean this, but we just looked at them do we think that and why?

Elisabeth talks later in the same interview about interpretation in mathematics:

> [Understanding] how to read a graph how to interpret numbers that people use really helps you understand data presented as fact or truth in the media, and so I think you could, I mean statistics are used to support arguments. Numbers are used all the time to validate people's positions on things because somehow that quantitative data feels nonnegotiable. You know a number is a number is a number, and you can't, you know… So, understanding what those numbers mean allows you to take a more critical look at

> whether it's true. You know how you interpret those numbers whether you believe them or not. It's really easy. I think a lot of people come out of school feeling like—math is hard, math is not something that I understand entirely. So, they are willing to take numbers at their face value and what I know to be true is that we interpret numbers in the media and in statistics numbers are interpreted.

Ayesha spoke about her recognition that there are multiple ways to present a topic to students:

> When I read something before I show it to my students, I am reading it with a very keen eye. Like what do I want the students, like so there's bias there. So, yeah, it's there. I do want them to have all of the perspectives, so sometimes I will choose something that I don't agree with, like I want them to know the truth, and so I will throw that out. But yeah, I think it does impact because even though I am being fair and providing all the things I'm sure that there are people out there that don't do that because they want that one point of view….

So, if we know there are multiple truths, then there will be conflicting truths. How might middle school students handle this? Ayesha describes a conversation she had with three students about evolution. One student said, "You can't believe in science and God, you can only do one." Ayesha replied, "I believe in science and god. I believe in evolution and god." Another student remarked, "You can't do that if you go in a church, and you tell them you want to be a scientist; they are going to say get out." Ayesha went on to wonder, "they are already starting to have these thoughts, so I am wondering when they started and how they have come to this age at 11 or 12 years old *knowing* these things…"

Students becoming capable and critical mathematicians. Both Ayesha and Elisabeth expressed one purpose of the course, or one way that they thought the course functioned was to help the students to become more capable and critical readers and writers of mathematics.

> **Susan:** How do you view the students as they come to you and what's your goal for them as they…?
>
> **Ayesha:** So, I actually, having taught some of the students before, I do have preconceived notions of some when they come, and I have concerns or expectations based on those preconceived notions. Some of them hold true and some of them don't, but my goal for each of them is that they find some joy. I guess in doing math that was a little bit challenging, so that they could know something, so that they could learn something bigger than math out of it.

> **Susan:** What's bigger than math?
>
> **Ayesha:** That they could know something that was real or true about the world because of math. And I, or that they could just know that they could know. Like, "I can figure this out. I've got this skill that allows me to know this thing or to think more deeply about this thing." I think that's the piece that feels… I want the kids to feel empowered to be able to ask questions when they see numbers anywhere and to know like, "Oh, they got those numbers from somewhere. I could get those numbers and check. I could know that. I could do that thing that they did. Maybe I can't do it right now, but someday I could do it." Anyone of them I would want them to think like, "I could be a NASA scientist. Really, there's so much more to it than just this rate business. But I see now that it's not as scary as it seems to take 5.88 billion and divide by 460,000 to find out the km per minute. I could do that." So, I want them to feel like—one, I can do that, and—two, I want to do that. I would love for them to think to be thinking I want to do this.

As Elisabeth talked about the course and her hopes for the students, truth came up as well:

> Reflection leads us to know things about ourselves that we maybe didn't know before and I think of that in terms of truth, I believe something about this situation and having looked at the numbers about it. It may have changed and that for me is now the true thing about this story. And math informed that or helped inform that true thing about the story. That idea of value in math, there are some numbers that are just the numbers and you don't, there's not much you can do but the truth of it I guess, the truth of those numbers is for kids is I can know this I can figure out how to do this. I can know this and that knowing feels like the truth in some ways like it's not a mystery anymore even if it is a mystery, there is a door open to the mystery so I can go through it and figure it out.

What does it mean to prepare students as mathematicians? As critical citizens? As truth seekers? Is questioning all numbers productive or is it crippling? When is questioning too much? When does it just hurt?

Pedagogical moves for uncertainty. Within the classroom practices there were moves that the teachers made consistently that opened up space in the mathematics classroom for uncertainty. In classroom observations, the teachers and I noticed that students engaged in vibrant conversations around the chosen topics. Unlike traditional mathematics classrooms, there was not a linear progression toward one right answer or a solution to a problem. Instead, the students and teachers worked toward and with multiple scenarios or possibilities in thinking about each current event. For example, when the students were studying the Ebola outbreaks of 2014, they read articles that reported that it was the "worst outbreak." In their investigation they

considered the question, what is worst? And how would we measure worst? When considered broadly and from various perspectives, the question of measuring and defining "worst" becomes an extremely difficult question to answer. Do we measure worst in number of deaths? In number of families affected? Percentage of the population? Cost to the country? Number of children who died? When the media reports that an outbreak was "the worst," our instinct is to take that assertion as true without asking about the assumptions that underlie that particular truth. This course asked students to notice and question their own assumptions and the assumptions of the media.

Guiding students in these types of discussions and helping them to check their own biases and privileges does not occur within the traditional pedagogies of the mathematics classroom. The exploration of these concepts and ideas demands a stance toward uncertainty and an openness to various and, at times, contradictory perspectives. The teachers in this study reported that students at varying mathematical ability levels (all above 40% on the mathematics section of computer-based assessment that the school gave at the beginning and end of each term) and from grades 6–8 were able to engage in questions of truth using mathematical tools when they held an uncertain stance and used strategies in the classroom that allowed all students space to think, consider, and speak their truth(s).

To scaffold students to suspend their belief and remain open to various versions of truths, the teachers built on several protocols from the professional development practices the school used. These protocols were designed to promote equity of voice and to encourage participants to be with a problem for sufficient time before jumping in to fix it. The teachers brought them without much change into the classroom to use with students.

For most topics, the teachers would begin by collecting images relating to the news topic and passing the photos around or having a set for each table. The students had quiet reflection

time and were asked to write about their reactions to the photos, what did they notice, what did they think was happening because of what they noticed, what questions did they have and what assumptions did they make. The teachers then used rounds to allow students to share; beginning always with what they could actually see in the photos versus conclusions they drew from what they saw. In the rounds, each student had time and space to speak, and students could pass if they wished. This practice helped students to notice their biases and see when they made assumptions based on what they saw. This practice translated for its use with movies and photographs to statistics.

Just like a photograph on the front page of the newspaper, a statistic gives a reader a split-second impression about a particular truth about an event or topic. As with the photograph, when the students and teacher interrogated the statistics and considered how they were constructed—what numbers and counting (A. Martin & Lynch, 2009) went into making them—then they could see that the statistics also were inherently biased. Every statistic is constructed by a person, so it is inherently biased, that does not mean that it does not speak to a truth, but that we need to consider from whose and what perspective it is built.

Discomfort in ethical and moral work. As the teachers planned the final unit of their course, I sat in on the planning session. Ayesha and Elisabeth began by saying that they did not want to take on a topic that was too depressing. They had just finished 10 weeks of difficult discussions during which students and the teachers were asked to bring more of themselves into the work of school than is typical. Halloween was just around the corner, so the teachers decided to begin a unit on candy. As they got further into this unit, they found that looking critically at this issue was also quite troubling. They watched videos about the use of sugar to hook consumers on particular products, and the damaging effects of sugar on our bodies. How is it that they always ended up in the place where they were discussing things that were troubling? Are we

finding disturbing truth(s) because we are looking for them? Or are they there whether we look or not, and it is our ethical duty to deconstruct them? What are the ethical and moral repercussions of bringing students and other teachers into the work of looking beyond the singular truth represented? Looking beyond the number and beyond the norm?

Denying access to truth. After a classroom observation on day, I witnessed a conversation between the two teachers. One teacher was relaying to the other that she would not be able to teach the enrichment math course Current Events Math in the next term, but rather she would be teaching a remediation math course. She was disappointed to have this switch and that there would be no enrichment math classes in the next term. She also expressed understanding that there were 7th graders that really needed support in their math and therefore it was okay to teach the remediation course. I asked the question, why is it that we think that we have to teach a remediation mathematics course in a different way than an enrichment mathematics course? Weren't the skills taught in the Current Events Math course important for those students in the remediation course as well? How would teaching basic or foundational skills out of a workbook to the 7th grade students function? Would they see themselves as distant from the mathematics, consumers of it, rather than as in relation with it? Don't we want all students to be critical readers of mathematical truth(s)? These questions, along with the others, lingered with me, how we make cuts not just between disciplines, but between pedagogies/classrooms.

Document analysis and truths on paper. As I consider the analysis of these documents in the poststructuralist frame, I began with Prior (2003), "a document and especially a document in use, can be considered as a site or field or research in itself" (p. x). Of these documents, following Prior, I ask: In what context was the document created? How does it function? How is it situated? For whom was it created? Who produced it? "What are the processes and circumstances in terms of which document x has been manufactured?" (p. 4) How does the

document function in a specific circumstance? “How exactly, and by whom, was this document assembled?” (p. 43)

I considered the documents in terms of the “fields, frames, and networks of action” (Prior, 2003, p. 2). Prior states that documents have at least two actions in the field, first as a receptacle (of instructions, commands, wishes, reports, etc.). Secondly, it enters the field as an agent in its own right. An as an agent a document is open to manipulation by others: as an ally, as a resource for further action, or as an enemy to be destroyed or suppressed. In addition to considering the particular documents, I analyze the images and graphs that were chosen to accompany them. Finally, I am interested in how these particular documents structured their readers (the students) toward particular ways of thinking or doing school, science, mathematics, and social studies.

Production of the initial document. The document being analyzed was co-constructed by two middle grades teachers. The document was designed as a part of a Learning Acceleration Period (LAP) course called Current Events Math (CEM). LAP is a 30-minute block that occurs four times a week. Students are placed in particular classes based on their scores on online standardized assessments that are given several times throughout the year. Students who score low (below 30%) are placed in a reading or math focused course. The school calls these remediation courses. In addition to the remediation courses there are “enrichment” courses. These courses are for students who score above 30% on the assessment. The CEM course is an enrichment course for mathematics. In the second term, when these documents were produced, there were two sections of CEM being taught. There are students from 6–8 grade in both sections. The two teachers of CEM planned the overall course and the units within the course together. The course consisted of several 2- to 3-week long units of study dedicated to particular current events. The documents analyzed here are from the European Refugee Crisis unit.

The initial document is titled “European Refugee Crisis” it consists of 13 questions that were answered in a series of several days in response to images, classroom discussion, and news articles.

The questions are as follows (each question has several blank lines beneath it). In parentheses are researcher responses to the questions:

1. Describe: What do you notice in the pictures? What do you see? (3 lines)
2. Interpret: What is happening? (2 lines) (This question positions the reader as a “knower” about the event and implies that there is a fixed answer. It does not read “what do you think is happening in this picture?” It positions the Western student as knower about the refugee, as though from seeing a picture or group of pictures we can know? Observation=knowledge=understanding.)

    a. Explain what I see. (2 lines) (Again, the student is structured here as being in a position to be able to explain “what” they see through a brief study of a photograph and to provide rationale for what is happening in the image.)

    b. Tell about my new insights. (2 lines). (The idea of insight here implies deep understanding of the topic, perhaps after 15 minutes of looking at the photograph(s). It positions the student as outsider as being able to know something substantial about the individual image or the larger conflict.)

    c. Find connections with other learning (2 lines) (This is the most open of the questions so far. I appreciate the suggestion of connecting to the image versus “knowing” something about it. I wonder how the use of other learning might steer the student toward connections that are academic or school related versus a questions such as: “What does this image make you think about?” or “What do you think when you see this picture?” Or even, “How do you feel when you see this image?”)

3. Evaluate: What is my opinion about this? or What is the value of it? Why do I think this? Make judgments that are clearly connected to observations I have made.) (4 lines. (They are not allowed to admit to unsupported beliefs—this is interesting—science based? Must see it for it to be true or have value. Can we make judgments that are not based on observations, but are based on feelings or thoughts about events—not direct observation?)

4. Plan: In what ways could this insight be useful to me in classes, at home, in my life in general? (3 lines) (In the span of four questions, we have already come back to how a middle school in America might “benefit” from the refugee crisis in Europe. This makes me wonder if these questions were somewhat standard prompts that did not translate well to this particular issue.)

5. Questions: What questions does this raise for me? (List as many as possible) (12 lines) (I appreciate the space for questions and the acknowledgement that there perhaps should be a lot of questions about these images, however, this comes a bit late in the sequence. I wonder about the prompts below: "Consider what you know about…." Could these read instead, "Consider what you don't know about …. "to open a space of uncertainty rather than certainty. This also positions the student/reader as central, that the exercise is about them without referencing what they are connecting to.)

    a. Consider what you know about the word Refugee—write the definition. (I am wondering how this leads to questions other than, what is a refugee?)
    b. Consider what you know about Asia- Middle East- Africa. (What bias is imbedded in this?)
    c. Consider what you know about conflicts
    d. Consider recent news about Europe- EU- United Nations.

6. Notice: Look at the maps in front of you what do you notice? (3 lines)

7. Interpret: What do you think the maps are about? (5 lines) (This question, unlike questions 2 and 3 above, includes an aspect of uncertainty. What do you think the maps are about?)

8. Are you able to label the map? List the countries or continents you recognize. (5 lines)

9. What questions do you have about the maps? (5 lines)

10. Look at the graph in front of you. What do you notice? (3 lines)

11. Interpret: What do you think the graph(s) is/are about? (5 lines)

12. Are you able to label the graph? (5 lines)

13. What questions do you have about the graph(s)? (5 lines)

The varying number of lines for student response would structure the students to write more or less in response to particular questions. In three different places in the document, there is a question that asks the reader to "notice" or "look" followed by a request to "interpret." These requests indicate that the creators of the document hold a belief that interpretations can be made through seeing and noticing. If interpretations are only made through seeing and noticing, what about our other senses, emotions, feelings? I wonder about the impact of science on research (and on this course) and how it might impact how the students and teachers are structured to

believe that knowledge is obtained or discovered. Question 3 asks the reader to "evaluate" and then in parentheses defines this as "Make judgments that are clearly connected to observations I have made." This statement reinforces the idea that we learn or know things through what we see and that we can/should only judge things based on what we can see. This statement might structure students to keep quiet about opinions that they may have about the photos and the people in them that might not be based in fact. How does this course position knowledge? From the teachers' perspectives this might prevent bias and prejudice from coming up and may make them feel "more safe" to talk about these topics. However, by asking students to keep these to themselves, the teachers may be giving the impression that these biases and prejudices do not matter as long as they are kept quiet. I wonder how the document could have allowed students to have opinions and reactions to the photos and then to recognize whether those opinions are based in observations or not.

Response to the document. The document was given to the students with little explanation other than the title. The students were given a set of pictures to look at as they answered the first 5 questions. Question 1 asked students to describe what they noticed in the pictures below:

The photos were chosen by the teachers to accompany the document.

The responses to the questions were as follows: [86]

Question 1:

Describe—

- Kids and adults walking away from places and they don't look happy at all.
- There are thousands and thousands of people living in tents or sheds.
- I see people near water.
- I see people standing huddles together with their lives packed up in a bag.
- Giant amounts of tents
- There are a lot of shelters and a lot of people. There are no roads besides the main one.

[86] I kept original student phrasing and spelling throughout.

- A bunch of huts, not good houses, no water.
- I see thousands of people trapped on a boat which seems to be in the middle of nowhere.
- People are carrying a bunch of stuff all going the same direction away from something.
- A lot of people are on a boat in the ocean squished together.
- I see what looks like innocent civilians on a boat and they look a little struggled. 11 people counted on one small boat and they seem like they are refugees.

Question 2:

Interpret—

a. What is happening? Explain what I see.
b. Tell about my new insights.
c. Find connections with other learning.

- They are trying to migrate to another country maybe. /no response/We have been learning about the refugee crisis a couple of weeks ago.
- People are fleeing their country. /There are so so many of them. /They are leaving because the war that is happening in their country.
- I see thousands of refugees fleeing on a boat. /I notice or guess this is how the package refugees. /I have heard of thousands being packed on boat, but this gave me a better understanding.
- People living in terrible housing. Why people leave–housing. (Interesting that the student even called it housing.)/I realized that people all over the world are unsafe and have to live in shacks. Why people leave–housing.
- I think there are a lot of refugees and they need shelter. Needs once they are gone /The refugees have made their own shelters. /We learned about this in humanities.
- People walking through a giant refugee camp. /I realized just how many/?
- I refugees with a bag of their belongings all huddled together. /It's sad emotion to see people without food to eat or a place to stay. /They look like the lost boys of Sudan.
- It looks like one is praying. /It looks like they are suffering. /A long walk to water.
- I see thousands of people having to try and make shelter
- It reminds me of the people around town living in tents but multiplied by thousands.
- People walking away from their homes with pretty much nothing.
- I have nothing to say.
- We are learning about the refugee crisis right now.
- It seems that they are all praying because of their poor living condition.

In these responses where the students were told to interpret and find connections, emotion and opinion came in more strongly. Five of the responses included a statement about movement or transition (leaving, fleeing, walking). Five referred to the number of refugees being large or larger than they thought (thousands, Giant refugee camp, a lot of refugees, there are so so many of them).

Question 3:

Evaluate—

What is my opinion about this? or What is the value of it? Why do I think this? (Make judgments that are clearly connected to observations I have made.)
Where are they trying to go? Question versus evaluation, perhaps signals the students unease with making a judgment without more information.

- It is sad. familys getting separated. People dying.
- No response.
- I wish these people had better housing and safety. I wish this wasn't going on and there wasn't as much of it.
- I think it cool that they made their own community.
- I think that it's really unfair that the population of Syria is being forced out of their homes because two groups have a battle against each other.
- I think that the government of these people should help them survive and look at a brighter future.
- I think it's sad and instead of doing math about it we should try to stop it.
- I think it's horrible that people have to live in shacks and tents and abandoned warehouses.
- I think that it's sad seeing so many young children having to leave behind everything they own.
- I think this looks a little sad. With all the adults and kids on board and with all of them looking for hope that they'll find some homes to live in.

Question 4:

Plan—

In what ways could this insight be useful to me in classes, at home, in my life in general?

- So, when about it in college or anytime we would already know about it.
- To try to stop it
- To be respectful for what I have and not be greedy and take things for granted.
- No response
- They can help me to be more grateful to my parents for what I have and how I live my life.
- I don't know how it could be helpful.
- Maybe to look more about this and find ways to help the cause.
- No response
- Knowing what's happening maybe try and stop it
- I am going to know about this, and I'll try to connect to this issue.

Question 5:

Questions—

- When are the Syrians going back? /How many people left Syria? How much of Europe is allowing refugees into their country?
- Where are they going? /What happened? /Why are they squished on a boat?
- Why don't they have shelter? /Why aren't they in a camp? /How did they get to Europe? /Why are they there?

- How big is this area? /How long have people lived here? /Will this ever end? /How many people are living here?
- No response
- Why are all of these refugees coming to this place and how? Why particular location
- I have no questions about this except why America doesn't help by bombing the terrorist's bases! (student drew a cartoon of a bomb hitting a building labeled "terrorists" with a blob labeled Syria yelling "yaay!!")
- Why are they refugees? Refugees from what? /where are they from? What conflict arose? /Is 11 people all that's onboard? Where was the photo taken? How can I help? Was this photo taken this year? When?
- Why don't they stay with other people? Where do they get food and water from? Why are there so many of them?
- Why is there a war? Is those all their possessions? Where are they going?
- Why are people migrating? /How do they survive? /Are they starving? /Are they dyeing? /How many will survive this? /Where do they get the tents? /How many children are forced to do this?

As I read through this document and the student responses, I was struck by how much an initial document can structure particular types of responses and how that structuring can be invisible unless you are looking for it. The number of lines and the types of questions perhaps led to the short responses. Though the brief responses could also have been a function of the short class period (30 minutes) in which the class took place, the general outlook of the teacher and the epistemological perspective she held, and how the students might have perceived her expectations or desires. The students' own interest in the topic or confidence to comment on the topic could have also played a role.

In terms of the content of the responses, I wonder at why race did not come up at all. Although all the people presented in the photos are black or brown, none of the students commented on race. I cannot assume that this omission is because the students did not notice that the people were non-white. Are they playing into a colorblind expectation in the classroom? Are they afraid to raise this issue, or feel that they do not have the right language or skills to raise this issue appropriately? Do these pictures simply meet their expectations of what refugees "should" look like; therefore, they do not question?

Course goals. In addition to the themes discussed above, the course was evaluated by the students and the teachers as to what it was for and what it did for them. When I asked Ayesha what she hoped that students will take away from the course, she stated:

> **Ayesha:** A sense of responsibility.
>
> **Susan:** To whom or to what?
>
> **Ayesha:** To those around them.
>
> **Susan:** What would that look like or sound like?
>
> **Ayesha:** People who are conscious of what is happening around them and are willing to speak up, are willing to try to learn more and willing to change if, not changing the world, changing their environment. Or if you like at the airport and you have someone who is very different that comes and sits next to you being comfortable in that situation.

Although the official course goals attend more specifically to mathematics and the state standards, Ayesha in this quote showed her attention to matters that might be considered to be outside the realm of mathematics. Elisabeth also saw a purpose to the course other than simply aligning to state standards when I asked her why she thought mathematics was important for her students in terms of current events. She responded at length:

> I think having a basic understanding of statistics in some ways, this is like the real-world math. Having a basic understanding of how to read a graph, how to interpret numbers that people use really helps you understand data presented as fact or truth in the media. I think statistics are used to support arguments, numbers are used all the time to validate people's positions on things because somehow, that quantitative data feels non-negotiable.
>
> A number is a number is a number and you can't ... And so, understanding what those numbers mean allow you to take a more critical look at whether it's true, how you interpret those numbers whether you believe them or not. It's really easy. I think a lot of people come out of school feeling like math is hard, math is something that I don't understand entirely and so they're willing to take numbers at their face value. What I know to be true is that we interpret numbers in the media and in statistics, numbers are interpreted.
>
> In some math, it's just the math. You can't interpret it. How fast did New Horizons go to get to Pluto? If it hadn't taken a gravitational sling shot around Jupiter, how long would it have taken? When it did, it changed its trajectory and the numbers changed. Those

> numbers are ... That happened, it travelled; it happened but there are other numbers that are more ... That are up for interpretation.
>
> We can say there aren't a lot of women game producers. Does that really matter? Why does that matter? Maybe men can be sensitive and thoughtful about the women characters they put in the games. Probably they can, are they? Then we have to take this number ... There's only 3 out of every 10 game producers who are women and we say, "Okay, so we know this number exists. We can say it matters or it doesn't matter, so let's look at another number, how many women are abused or raped or, in other ways, mistreated in games in general?"
>
> Well, what? Is it 70%? Because that's the number of ... Or is it a different number from that, and so what is that? How can those numbers inform what we think or speculate about? And then we can ask questions. As soon as we are willing to look at numbers and add our own questions about them, I think we can get a much deeper understanding of what's really happening in the situation, and how our own beliefs, opinions and prejudices influence what we think about them? That was really vague but—
>
> (*Pause*)
>
> I think giving that to kids, giving kids that tool and saying, "There are grownups who write these articles. The media is full of people who will tell you how it is and they'll use numbers to do that, but if you understand that there's a place you can find those numbers and think about them for yourself, like that, that's really empowering." For a student to look at what Rand Paul said and say, "I can figure out if he's telling the truth or not." That's awesome. That's an awesome thing to be able to do, to look at the Ebola crisis and say, you know, watch the headlines, this is, you know, this is the worst ever, but really come down to the question of what does worst mean. I've looked at all these cases of Ebola and really, the worst that ... Chances of you dying in 1999 ... I don't remember when the outbreak was, you had an 8 in 10 chance of dying in that one, but you've only got a 4 in 10 chance of dying in this one, so what does worst mean?
>
> I think it's really powerful for kids to say, "I can, I can think about what that means, and I might be willing to say this isn't the worst but why?" so…

Here, Elisabeth expresses her belief in mathematics embedded in context and process, that students need to be able to make critical decisions. This perspective informed the ways that she and Ayesha structured the course.

The students responded on their written course survey's when asked "How was the course useful?" as follows:

- It gave me a way to connect other subjects to math
- I know now there are things bigger than myself
- I was not the best in math, but I learned a lot

- It made me better in math
- I learned new things
- You can be aware of things that are happening in our community
- I think it helped grow my math skills more
- It gave me a challenge
- I learned scientific notation
- It was useful because it helped a lot in MST
- I realized other things going on in the world

CHAPTER 5: INVENTIVE LINES OF CONNECTION

> Apparatuses are not preexisting or fixed entities; they are themselves constituted through particular practices that are perpetually open to rearrangements, rearticulations, and other reworkings. This is part of the creativity and difficulty of doing science: getting the instrumentation to work in a particular way for a particular purpose (which is always open to being changed during the experiment as different insights are gained).
>
> – Barad, 2007, p. 203

I entered this dissertation with an idea that was bold for me, one that I had been resisting. I wanted to situate the dissertation as doing science. Early in my doctoral program, I pushed back against the methods, the procedures, the ways of coming to know that seemed too linear, too prescribed. And I associated science with these linear and prescribed ways of knowing. I greedily took up the criticism of science and its positivist notions. In the neoliberal academy, where research practices are increasingly controlled and regulated (Koro-Ljungberg & Barko, 2012), I did not want to be controlled. This desire emanated in part from the specific material arrangement or my life thus far with my husband and father, the ways that my body, mind, and feelings were positioned as outside of my purview. I did not want to be controlled—told what to do, how to feel, what I could know. I had enacted hard and permanent boundaries and binaries that placed me on the other side of science.

Barad (2007) invited me to think science differently, to move toward science again. This moving toward has been complicated, and from that complexity, moments of creativity have arisen. It was easier in a way to dismiss science and objectivity outright, to forgo the mask of validity. Now, I grapple with a diffractive methodology, which I am responsible to and for particular material arrangements, the fine details of the literature and the knowledge production. I am responsible to the cuts that are enacted in this research and yet not in control as the agency is distributed across the phenomena of which I am a part. Although this could make me feel absolved of responsibility, I feel a greater sense of responsibility in how I present this research,

yet I know that I cannot attend to all the cuts and marks on bodies that will result. I am a just one inseparable part of this knowledge making apparatus.

I look back on this work and wonder how did this instrumentation (this dissertation) work—in what particular ways and for what purposes, to use Barad's (2007) language. How did enacting data in these ways matter for students and schools? How might it matter? How does it matter for my participants? How did enacting data in these ways through this dissertation constitute me as researcher? Barad asserts repeatedly throughout her writing that diffraction is an affirmative and ethical practice and involves responsibility to the other—not the exteriorized other but an other within. How has this work affirmed? What has it affirmed? Who has this work affirmed? If I were to try to map the bodies to which I feel response-ability, I would name my participants, my committee, the academic fields within which I am working, teachers, students, scholars whose work I am citing (or not citing), and the academic subject (the one with a clear trajectory perhaps) that I am becoming.

A part of the work of the dissertation was to affirm other knowledges and ways of knowing and to consider how those ways of knowing mattered for schools and students. I thought my data with an interpretivist frame and within a poststructuralist frame attending to each in a thought experiment. I did this in intra-action with Gutiérrez's (2017) argument for other knowledges and Kimmerer's (2013) insistence on complementary knowledges and with D. B. Martin and colleagues (2010) assertion that what gets to count in mathematics education research must be troubled, not for the sake of troubling but for the material conditions that are enacted when particular ways of knowing are excluded. I did this in intra-action and responsibility to the students whose bodies and lives that are not counted as mathematical enough, the students who came into my classroom and did not feel that they could connect to this thing that was mathematics.

I attended to uncertainty and truths about mathematics as a way of working against particular notions of what counts as mathematics and who counts as mathematician. The concept of the liminal made this possible for me. Yet, I have not felt "math-y" enough in many of the spacetimematterings in relation with this dissertation. Uncertainty, liminality, and inventive lines of connection were ways of building a string figure that I would be attached enough to mathematics, attached enough to get a job, to be taken seriously, to be legitimate. In order to be in mathematics, I had to radically reconfigure for myself what counts as mathematics education research, building on the work and confidence of those before me.

Belt in Intra-action

If I can just write one more paragraph
Coffee in the air and on my breath
Husband moving about
Cursor blinking
Numbers turning over
I'm late
Do I go?
Can I miss today?
But I'm missing tomorrow and Friday, I have to go.
Shoving papers into my backpack
How is there no traffic? I can't believe it
Pulling up 3 minutes early
Rushing into the office
Still time for niceties?
Climbing steps no hurry now
Deep breaths

Round the corner to Elisabeth's back in the door frame
Posture of acceptance or reluctance or refusal?
That other teacher is there
Who cannot be named
Not on that irb

Class should have started what are they doing
Why are they just chatting?
The kids are clearly distracted. I hear loud noises, I slide past them into the room and then regret it immediately.
Does she want me here am I welcome?
She smiles… ok

Dónde está Costa Rica
Dónde está Costa Rica
Dónde está Costa Rica

I open my journal pick up my pen
I close it
What will I write?

(*When I entered the room, students were up out of their seats talking loudly, one boy screaming about Costa Rica. The teacher stands at the door talking to another teacher. Seven students are at their desks. 9 are standing. There are 6 boys, 10 girls, and 5 African Americans. The board reads…*)

Is that the data you want?
I can't write that not today.

Elisabeth brings a belt to the desk where I repose
I ask is it ok for me to be here?
Yes
There
Is
Just
Some
Drama
Today.

(*Are teachers allowed space to react to things? To handle the unexpected, to talk out the difficult things, or are we supposed to turn that off when the bell rings. Must we always be on schedule…*)

Can I help?

(*Finally, I come to my senses… am I still a researcher if I don't write in the book. Does the pen have to be in hand?*)

She walks to the front of the room
The ghost of the drama, the child, the emotion, the fear
On her face

I pass out the papers
Then something peeks my interest (dangerous thing)
And I return to the grid page and move the green pen across
Capturing that moment
Getting it down just right

A student comes to the desk as Elisabeth gives directions
She picks up the belt and looks around
What do you need? I say.

Do you know where the stapler is?
Can it wait until she is done giving directions? Whispering
I don't want my pants to fall down.
A pause.
How about I fix it for you? Were you going to staple it?
Yes.
I'll take care of it.
Am I being responsible now? To whom? Do I just not want to think about what to write in that book?

I stand trying not to draw attention, the students are focused the other way.
I search through Elisabeth's cabinets one at a time.
Maybe a bit of string?
I could weave it back together.
Grocery bags.
Bins of paper.
Stubby pencils.
Granola bars.
Pencil sharpeners.
Tennis balls.
Balloons.
Glue.
Sudoku.
Blokus.
Set. (*Ah my math club mornings playing set, I need to get one of those*)
Ring binders.
Duct tape.
Yellow
Green
Grey
What color would she like?
Should I ask her?
Don't want to interrupt class?
I cut three pieces and wrap them around the belt.
Pull it tight.
And again.
The class has transitioned to group work.

I walk the belt over apprehensively.
I wasn't sure that the staples would hold and was afraid they would poke you.

So
I
taped
it?

Thanks
I just went to the bathroom and pulled it tight and it just snapped.

It was my mom's.

I look worried, I guess.
Its ok she gave it to me. She won't care.

Is it ok?
Yes, thanks.

I like the flash of yellow.

I head back to my desk.
Students are beckoning Elisabeth from every direction.
I don't see pita on this list.
Where's bacon?
I can't remember what I ate for breakfast.

Step away from the desk Susan.
Step away from the research.
Be a teacher.
Be.
Be.

I turn to the nearest loudest voice.
How are you doing? Can I help?
For the next ten minutes, I flip through pages on calorie charts trying to find granola bar, and chili, and turkey sausage.
I answer questions. The room begins to settle.
We are beginning to keep up with them.

At the end of class, the student with the belt comes up again.
Thanks for fixing it.

You're welcome.
Thanks for bringing me out from behind the desk. What am I looking for? What will I find if I look for it? What if I stop looking for it? What might I find then?

Limitations/Liminalities/Fieldings

I found joy and tension in the field crossings, in enacting cuts across and within fields, and in looking differently. I veered off into spaces that did not seem to be productive or useful or on topic. I snuck out past curfew to play in other fields with the thrill of being caught. I wondered at times if I could be so utterly lost and still have joy in the present. And in writing this dissertation, I know I have more questions than answers and perhaps it would be a joyful

perplexity, if it were not for the responsibility to make this dissertation work for students to make it matter for someone's life other than mine. How do I make the data that I collected matter? How do I make the time that the participants gave me worth it? These questions haunt me, and yet I know that they are embedded in a cause-effect paradigm that does not hold up. The research has already mattered, and I attended to the relationships in ongoing intra-actions. Cuts have been made, boundaries have been enacted, and they continue to shift and stretch. The ethics of the research cannot be measured by what knowledge is produced in the form of manuscripts or dissertations, it has already and will continue to be enacted in the ongoing co-constituted becomings of which it is a part.

Barad (2007) described the brittle star as "living breathing mutating liminal diffraction gratings… negotiating complex sets of changing relations" (p. 377). She goes on to explain that there is a "creative tension between resolution of detail and visual acuity" (p. 378) for the brittle star. They sacrifice resolution for wide views, and they constantly renegotiate the boundaries of their bodies in response to predators and other aspects of their environment. They enact cuts and defy stable subject-object notions. Although I can try to write about Barad's ethico-onto-epistemology, I am no brittlestar. Although I acknowledge and recognize my inseparability from the phenomenon of which I am a part, I still hold onto the humanist I. It is hard to escape given the intra-actions that have brought me to this here-now.

Perhaps, in trying to take up diffraction, I am being responsible to these ways of knowing that overlap in my ongoing intra-actions with theory and method. I am moving toward something that looks like nothing and trying to trust that I will not understand it from afar but will become with it (as a part of an entangled phenomena) and that that becoming will matter for schools and students.

In looking back at the knowledge making apparatuses that I have laid out in these chapters, I have moved across and between these two readings to see how they matter to me in writing them and to consider how they might matter to the field(s) that they might enter, the fields that are already co-constituting them. In considering the two perspectives and how they matter. I am not trying to triangulate and argue that if I look at a data set or classroom from multiple perspectives, then I could learn the essence of that data or get closer to the one essential truth of uncertainty in mathematics or statistical literacy in middle school. Instead, I have argued for multiple perspectives because the specific material arrangements of our knowledge making practices produce different knowledges that matter for school mathematics differently. These two knowledge making apparatuses create different phenomena. Both are valuable and have affordances for how we think about teaching students' mathematics and statistics and about being with students. Both are accountable to marks that were made in their enactment.

Interpretivist–Methodologist–Mathematician–Teacher–TMfSJ–Researcher–Wife

Statistical literacy came to dominate the interpretivist knowledge making apparatus. It drove the purpose for the research and why it mattered. It was legible within an emerging field of statistics education research, it came into intra-action with big data and the data deluge and gained speed. The lines of connection between statistics educators' views of data and qualitative researchers' views of data also increased the momentum of this apparatus. Statistics education research and statistical literacy and the lines I could create between them and my data, gave the research legitimacy and relevancy. I could argue how the teachers were building statistical thinking dispositions and using an interrogative cycle. The research mapped neatly onto this field. This mapping mattered in both the production of me as mathematics education researcher and the production of the research as legible.

Poststructuralist–Truthfinder–Unbecoming Wife–Becoming Scholar

The poststructuralist reading happened in a spacetimemattering that was interlaced with uncertainty and questions of responsibility and truth. In the intra-actions that produced what I call the reading, I was attending to responsibility to my participants and how my presence in the room mattered. I was self-conscious in asking for anything from them and did not want to disturb even as the theories I was reading told me I was already always disturbing. My neutrality had been taken from me and I became hyper aware of having an impact of mattering in the space.

I was uncertain in my intra-actions and entangled with uncertainty in my readings. I was reading Ernest (2016) and Edgoose (2005) and Caputo (2012). The diffractive question is the effect of this specific material arrangement. In considering the boundaries that were enacted in this phenomenon, I resisted methods (as I performed them) and the sensible, privileging the sensational and other ways of knowing. I stopped mid transcription to collage and color and question (Cannon, 2018). In this knowledge making apparatus, I was not linear and allowed the material, affective, and nonmathematical in. I wrote about what happened in the hallways and in between observations. I noted conversations about chickens and what was on the lunch board. I did this partly in attention to ideas of rich detail and an objectivity that demands that I capture everything without judgment. I also attended to these details because they seemed to matter, and they make a difference in the knowledge that is produced.

The effect of this specific material arrangement as I was reading Ernest (2016) describing how “mathematics engulfs, tames and appropriates any troubling concepts and thus smooths away uncertainties” (p. 391), I was attempting to take up methods that did not smooth away the snags and excess. Instead, I iterated and overproduced, I leaned into the excess creating ten transcriptions none of which was certain. I began to believe that if certainty in mathematics had been produced through social interactions and school mathematics, then a belief in uncertainty in

mathematics can also be produced and if certainty in methods could be produced, so could an uncertainty in methods.

I saw this uncertainty as liveliness, and it was affirming. In classroom observations, when discussing an image of refuges or a video about concussions, students engaged in vibrant conversations around the chosen topics. Unlike traditional mathematics classrooms, there was not a linear progression toward one right answer or a solution to a problem. Instead, the students and teachers worked toward and with multiple scenarios or possibilities in thinking about each current event. For example, when the students were studying the Ebola outbreaks of 2014 and considering the multiple ways to measure "worst," they produced many conflicting yet viable solutions. They then had to debate and argue why they had chosen to measure worst in the way that they had and how they had used mathematics as a tool to support their position. The course asked students to notice and question their own and the media's assumptions and to use mathematics to consider "the answer" in various ways. Students quickly were confronted with the idea that there could be many conflicting, yet, viable answers to a question.

This view of mathematics as multiple and the repeated assertion by teachers that there could be multiple right answers to a question opened a space for uncertainty in the mathematics classroom. This uncertainty was not a blank uncertainty of not knowing anything, but an open uncertainty of considering multiple views. This deliberate practice allowed students to construct a new way of being in the mathematics classroom. Could mathematics become less sterile and static through these intra-actions? Or become differently? Could students who had not seen themselves as becoming mathematicians envision a crack, a liminal space where they might squeeze through? Would they have to make themselves small to do that? Trim off the excess to fit? Were new cuts being enacted? And what excess was produced, extra appendages reaching out?

Through my intra-actions with the teachers in interviews and hallway conversations, I noticed that their views on mathematics shifted. A boundary shifted in the intra-action of this research. From the first to the last interviews, the teachers began to question statistics as absolute truths. The teachers began to take notice of how their taken-for-granted assumptions about data and numbers were operating in their presentation of content to students and their interactions. In their conversations with me, they would often make a statement about mathematics as truth and then pause and notice their assumption and rethink it. A self-consciousness developed because of their engagement with the phenomena that was/is this research. A mark was made on their bodies that affected how they thought themselves as mathematics teachers.

Betweenness

As I have repeated throughout this dissertation, neither of these readings is more or less true, but each affirms and affords something different. The readings were not linear and clean, first one, then the other, then the other. I enacted boundaries and then made new cuts and boundaries, reworking what counted. It was always between: between spaces, between times, between fields, between versions of me as researcher. There are no clean versions or representations of what research would look like in a particular paradigm in some pure way. They are always already mixed up, so what is the use of the thought experiment? Or doing science in this way? What are the thick moments of the study?[87]

[87] I had turned in the first version of my dissertation to my advisor and finally felt permission to go back to reading. I read article after article from the pile that I had collected about how diffraction is being taken up in various spaces, diffraction and Don Draper, diffraction and Bergson, diffraction and Deleuze. I had already read almost all the articles at least once, and then I read them against my dissertation with an apricot thumbprint cookie and some mint tea. Some of my notes in the margin were foreign to me although they were in my hand. Diffraction, the concept, diffracted, as well it should, shooting out into different versions of itself, fringed edges showing, bands of light within the shadow.

Where in the readings and writings and workings, does the movement[88] come into phase, and align and pick up speed? And where did it go out of phase and snag and stick? As Barad (2014) states, "we re-turn to thicker[89] 'moment[s]' of spacetimemattering" (p. 168). There were tangles and catches and bulky places in this research. Moments where I felt resonances, moments where I was pushed or pulled.

In trying to cross fields and be between, in attempting to undo binaries, it made it hard to place this research or to place me. We became "dislocated from the available maps specifying kinds of actors and kinds of narratives" (Haraway, 1992, p. 299). I was not readable at times as doing science in mathematics education. As I look back over this dissertation and what it has become, I am fascinated by the story I have allowed it to tell (i.e., the story that I see it telling). In "producing" this "product," while entangled in the job search process and resulting campus visits, I see how my attention to legitimization and legibility pulled this knowledge making apparatus toward interpretivist and poststructuralist versions. Pulled toward stories that could be told in research presentations and understood by faculty hiring committees. Whereas at the beginning of the writing (the putting of words on screen) for this dissertation, I was most interested in ideas of making kin (Haraway, 2016), the posthuman (Braidotti, 2013), and technicity (Manning & Massumi, 2014), these ideas became too much for this dissertation. The knowledge making apparatus that is dissertation does not allow too many philosophers or too many ideas. I needed to settle in on one. Yet, they are also here, though perhaps they do not

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[88] "How counterintuitive, then, to approach autistic movement—or any movement instruction, for that matter—from the perspective that there is a definable frame as regards to where movement begins and ends?" (Manning, 2016b, p. 121)

[89] In one of these thicker moments, I am hitting my hand against my other hand resisting a subject that I do not think I want to become, buying a version of difference that Trinh Minh-ha worked against and Barad (2014) described as a "colonizing logic whereby the 'self' maintains and stabilizes itself by eliminating or dominating what it takes to be the other, the non-I" (p. 168).

show so explicitly. They are between the lines. And the agential realist accounting exists in the between as well. Barad (1996) stated, "knowledge comes from the 'between' of nature-culture, object-subject, matter-meaning" (p. 188). In this betweenness, in the liminal, in the crossings there is sensation, sometimes sensation that is joyful, and sometimes sensation that seems to tug at the binding of my being. So, I come back to my question from the beginning of this writing. A question that has no beginning or end as it seems to span my lifetime. Can I bring lightness, joy, and play into my research and break the divides between life and work? Do I even want to do that? Would it be safer in this neoliberal academy to firm up the boundaries between life and work instead? Taylor and Blaise (2014) ask researchers to

> be a bit more flirtatious with the non-human world. For it is only if we can risk not already knowing, and keep a space open to the ways that the world might move us, that we can continue to be disconcerted, baffled and generally stimulated and enlivened by its inherent queerness. (p. 389)

I want this to be enough, to be enough to move me and enough to impact[90] schools. I wonder if this is enough. Perhaps it is part of what we do while we do the other work, the work that legitimizes us as fit for the neoliberal academy. I also wonder how we keep the non-human in research. Perhaps it is just through flirtations for now. It comes in interludes and footnotes that readers might skim over. It lurks at the edges, the outside within. It makes a cut, a mark on the body of this dissertation.

[90] I shudder at this word as it escapes my fingers. Usually, I think it and erase it. But here I keep it in as evidence of the knowledge making apparatus of which I am apart. One that conditions and disciplines me toward impact and counting and … … …

Doing Science: Findings?

> We are concerned with social and political pressures to oversimplify and promote definite, simplified, and ultimate answers even when studying complex and multidimensional educational problems. These political pressure points steer researchers to focus on outcomes rather than paying attention to the processes that generate particular types of answers.
>
> – Koro-Ljungberg & Barko, 2012, p. 80

I should for a moment return to the spacetimemattering that began this dissertation and consider the questions I asked then:

1. How are data produced through the interaction of participants, site, context, theoretical framework, materials, methods and processes?
2. How are data productive of different knowledges/ways of thinking/questions in various entanglements and configurations?
3. How might multiplicity in method and theory open up potentials for different views of knowledge and truth, validity and responsibility?

Although I resist findings and tend toward perhaps, I should say why I think this work is important, clearly state why I think it matters. This work disrupts boundaries (Smythe et al., 2017) in educational research specifically as it relates to data and it uses to construct truths about teachers, students, and schools. As numbers and statistics are being used more and more to represent, count, and sort in education, I do not suggest that data/numbers be abandoned, but rather that educational researchers, teachers, and administrators carefully consider the specific material arrangements of the knowledge making practices that are used to construct truths about students and schools—and themselves.

What answers do I have? What have I come to know, objectively? I have moved across fields and data configurations, attending to the specific material arrangements. Perhaps my initial resistance to science had to do with its application and transfer across fields without sufficient

attention to how a particular practice might function *there* in *that* field. And I wonder if attention is enough. Education is particularly messy in terms of specific material configurations. How can I imagine that I might know how a student came to learn something? Or to behave in a certain way? Koro-Ljungberg and Barko (2012) argue that focusing on answers can foreclose other processes of knowing. In doing science this way in this dissertation, what processes of knowing have I foreclosed?

Koro-Ljungberg and Barko (2012) also attest that answers to research questions should be beginnings and should provide multiple entry points. I feel as though I have only just begun to think with this data and only scratched the surface of the questions that I could ask of it or that it could ask of me, or in Barad's view how we might be reconfigured together, perhaps radically.

I am left wondering how radical reconfiguration might happen. What are the conditions for its emergence? I feel radically reconfigured—I did not plan or expect to be. I look back and think that I became with poststructuralist (and posthumanist) theories because I desired a radical reconfiguration, and they were the only theories that would allow me to think myself into a different way of living.

How do we as mathematics education researchers think school mathematics into other spaces? Can we aim to or intend to radically reconfigure something else? Does this need to be serious and depressing work, or can it be joyful?[91] In my work, I have sought out academic joyrides[92] and focused in on the idea of joyful perplexity. Barad (2014) wrote of "happily creating diffraction patterns" (p. 172) with Gloria Anzaldúa. Perhaps these are the times when

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[91] Although I resist binaries, they return. I point to this one to remind myself of the apparatus within which I work, and one that I wonder if I should resist or affirm. (Another binary—really, I did not mean to.) Can I just notice them coming along, like in meditation? There is a binary, there's another and another? Does resisting just give more power?

[92] This term is one that Dr. Holbrook and I use to describe taking unexpected invitations to read into spaces considered outside academia or outside of our fields.

lines of inventive connection emerge, erupt, like fireworks that you thought were duds. When I see something in another field that is affirming and that undermines difference as binary, I feel pulled to follow the joyous possibilities this affirmation leads to. The surprise and making kin in a place that you thought was filled with strangers.

In rethinking with Haraway's (2016) string figures and lines of connection and thinking with "dynamic links' that van der Tuin (2014) proposed and diffraction as "showing difference differing" (p. 236), I wonder how I am becoming in relation as academic subject and how I am doing science in particular ways. Perhaps this dissertation is hard because I have been trying to hold the string figure still for too long, my fingers tremble and are marked with deep groves as if I have been flossing for hours. The grooves fade, yet return the next day, the marks linger even once the string is gone and inform the next figure, it is a (re)turning. And I have to hold it still, or stillish, for the 200 pages of this dissertation, so that it is legitimate and somewhat linear, and I can be a coherent scholar. Is there another way? Could I have written a dissertation and allowed for dynamic links that would weave mobile string figures? Is that the dangerous move? Or is what I am attempting the more dangerous thing—pretending that something is still that is not?

As I think about making inventive lines of connection and making kin and how I might show them to a reader, I know I will kill them in order to hold them still. They fleet across in front of me. I could perhaps pin one down to the board, wings outstretched shimmering, or with the hint of shimmer lost. In freezing it for closer scrutiny, the liveliness is gone. I have made a cut and drawn a line between it as an object on the board to be studied and me as scientist objectively looking on measuring wing spans and tracing patterns. And then and there it is reduced to a series of measurements, and I, the piercer of wings and the killer of flight, am erased from the phenomenon.

Intra-action That Made Elisabeth Subject[93]

The subject/object cut continues to be materially/discursively manifested and produced in my interactions with Elisabeth, one of my participants. I worked with Elisabeth for 5 years. She was a colleague and friend. One of the people whose opinion I relied on and in whom I trusted to be rational and considerate. After I entered my doctoral program, I kept in touch and in the spring of my first year as a student I met up with her. She told me about the LAP course that she had been teaching that semester. I was intrigued and excited. I did not know then how far reaching that decision would be and how it would impact our relations. I was warned in my research methods courses that I should not do work with people or in places that were well known to me, but that caution was focused around a concern for trustworthiness and validity, concerns of which I found myself skeptical.

In beginning this project, engaged in the research apparatus, a cut was enacted between Elisabeth and me. She was produced and continues to be produced as object and I was and am produced as the subject that has the right to study her. Western research epistemologies have a colonizing effect and structure the participant as an other while the researcher maintains privacy and distance. In this dissertation, I have worked to invade my life and thoughts and stories, even as my participants lives are put on paper, and "permanent marks …[are] left on bodies" (Barad, 2007, p. 119). Whereas before Elisabeth had been seen and thought by me as colleague/friend/confident, now the mark of participant has been left on her body. Even seeing her now after this study has been closed through IRB, I cannot unsee the marks of participant on

[93] As I noted earlier, I was struck by how the agential realist versions seemed to escape my dissertation, and I also recognize that the whole overarching framework relies on agential realist ethico-onto-epistemology. Does it not count because it is not named and categorized and produced as an iteration? Yet, the dissertation would not exist in this form without Barad. Still I am tempted and will give in to that temptation to include a few interludes that speak to the materiality and how the agential realist account might show itself.

her. On the one hand, I regret that, our relationship will never be the same as it was; on the other, I could not have had two more gracious and compassionate participants than the two I had in this project. For all of my ongoing apologizing they continued to reassure me. I wonder if my apologizing was a way to get that reassurance in fact. That I was ok. Not just as a researcher, but as a person in the world.

Methods Out of Time, Data Enactments

As I entangled with data and theory in various spacetimematterings and considered the flows and pulses and snags that are produced in and out of time in this project. Data "transform[ed] themselves" (Koro-Ljungberg et al., 2018, p. 471) with me and theory as we become together. We flowed and paused and snagged in diffractive patterns of amplification and resonance. As I took up the initial set of data—documents, and audio recordings, and field notes, and images—again and again with other materials and another body—surgically altered, materially different, and with different theories and readings, data were created again through my intra-actions with them. Data production became both flattened in terms of hierarchies and entangled in terms of agency. Data production occurred in the field, the site of research, and then again in the fields of qualitative inquiry, mathematics education, and statistics education. I gesture at the complexity of data production only points to the entangled nature of our becomings and the futures yet to be made.

I found that the linearity of the apparatus I initially designed with clean lines from theory to output were insufficient. I was always already zigzagged between and amongst theories and texts. Diffraction is out of time. I could not put down one theory and set it to the side and pick up another. My body showed the scars of my entanglement in poststructural theory. I was made and unmade through my readings and entanglement with the data/theory. I also found that the fields I

was producing for and being produced for reconfigured the data/me to fit within their malleable confines.

When/where there were snags and excesses in the productions, I lingered with them to see what might come (Manning, 2016a),[94] where repetition might lead to invention. Although I imagined I might be able to consider the data with each theory neatly (resting in my humanist notions), I found that I zigzagged between theory—or that theory pulled or pushed me as the data/theory/materials acted on/with me. As Barad (2014) attests, there is "no absolute boundary between here–now and there–then" (p. 168). Diffraction is not a set process or pattern. It is iterative. In becoming researcher with this data and these theoretical texts, I was radically reconfigured and became unable to see data in fixed ways. Poetic and material data productions crept into the traditional text— "the physical phenomenon of diffraction makes manifest the extraordinary liveliness of the world" (Barad, 2007, p. 91). The assumptions and taken for granted ontological commitments of the theories wound around the data and me and reconfigured us into another body, and none of this entanglement can be undone.

Lenz Taguchi (2012) cautions/informs us that diffractive analysis "relies on researcher's ability to make matter intelligible in new ways and to imagine other possible realities presented in the data" (p. 267), so I pause here with an acknowledgement of the limitations of my imagination as to the iterations produced already and confess that

[94] I have mostly relegated Manning to the footnotes and parenthetical notations in this dissertation; however, in being true to the specific material arrangements of this knowledge making apparatus, she has been by my side throughout. I have been reading and reading her books alone and with others and thinking with her ideas for manuscripts throughout the writing of this dissertation, her philosophy which I think diffracted across Barad's is present throughout, even if it is not often named. This was an intentional move to make this dissertation more legible as legitimate in taking up one theory carefully versus flitting and flirting with multiple theorists.

data/researcher/material/theory/spacetime continues to produce beyond what I can know/become/write/tell.

Throughout the study, I read and listened to old data with theories and methods typically placed in the interpretivist, poststructuralist, and agential realist perspective and created other productions—poems, collages, audio, text—at/in different spacetime configurations. The apparatus is "tuned to the particularities of the entanglements at hand" (Barad, 2007, p.74) and those particularities were noted as much as possible. As Smythe and colleagues (2017) explain, "our research apparatuses create the phenomena… and we are responsible and accountable to these" (p. 180). The goal of this entanglement is insight into other possible arrangements, not to repeat or duplicate arrangements as that is not possible. Data perform in one way as one thing under certain conditions and as another thing under other conditions. "Quantum entanglements require/inspire a different sense of a-count-ability, a different arithmetic, a different calculus of response-ability" (Barad, 2010, p. 251) to all of these conditions.

In the interpretivist version it was easy to map things onto the predetermined dimensions and to have them lay there, still and well behaved. Anything that did not fit was excess pushed out and did not count. It was not allowed to count. Once I had the model to align to and the dispositions to slot to, it was easy to push things into their places. Perhaps it would be more reliable if I had had another person code the data to the dispositions? It reminds me of the species of lizards in Alice Fulton's poem that were not discovered because they were thought to be impossible. What else might we be missing? In the interpretivist version the method was the theory. It was method that I was attending to being good observer and interviewer and to code according to the code book. The theory that drove this part was being "good" qualitative researcher—the intra-action was geared toward doing science in particular acceptable ways. To be legitimate. To be legible.

Ethico-onto-epistemology

Smythe and colleagues (2017) consider their research to be deeply ethical and flattening allows an opening up that can create concepts that are

> not just responding to the given or communicating what we found. It is not just about enabling us to know and interpret the present as it is domesticated and performed in life "as it really is." It is about transforming life. (p. 185)

Thus, research becomes something that effects educational spaces, not something that studies what happened *in* them. Research in this sense is not about producing a more exact or faithful representation of the site, the participant, the theory, or the data, but rather it "helps us question assumptions about how we conceive of learning and teaching" (p. 22) and how we might live differently. Researcher, data, site, knowledge, theory are co-constituted through particular arrangements. This study sought to consider how the differences in those arrangements come to matter and to allow imaginings of new ways of living and the reconfigurations of concepts.

Knowing and being are entangled and co-constituted and ethical matters, as Barad (2007) attests, are also inextricably tied to knowledge production. If how we come to know matters for what we know then each moment of knowing/being is an ethical relation. The particular entanglements of researcher/theory/data/participant/materials/texts matter for knowledge and subject productions. Diffraction engages with data in an inventive and creative endeavor—an ontology of immanence (St. Pierre, 2018), and although I cannot control what becomes, my actions in our mutual becomings are ethical response-abilities (Barad, 2012).

There are important questions that this study brings to light that could be asked in other places and spaces. The multiple and overlapping layers of ethics—ethics of the researcher in the field, ethics of the teacher toward her students, ethics of the citizen in a community, ethics of representation in the media—are ever present. Even as I make moves, the context changes and I

wonder how to move responsibly. In Todd's (2003) thinking about responsibility, ethics and relationships, she stated:

> What counts as ethical in Levinas's thought is not encapsulated within rule-governed behaviours, ethical codes, or moral precepts that can be secured through stable significations. Rather, the ethical lies within the very ambiguity of communication, within that which slips our cognitive grasp and possession…. For Levinas, communication is inherently ambiguous because it gestures beyond any stable meaning toward the very otherness of the other that marks her as radically distinct from myself. And it is this relation to the other as one of unknowability where the ethical promise—and risk—of ambiguity lies. (p. 33)

If we think back to the football players at the table with the other students, asserting their truth that went against the numbers, I wonder about the truth of experience understood through relationship with others. Should the other students have believed the experience of a person they had a relationship with, or the number derived from many instances and published by scientists?

Is the responsible, ethical thing to do then to continually create new interpretations and representations based on the particular context? To iterate and iterate. Is iteration ethical if there is no "right" to get to, no certainty that can calm us? Is the calm in the acceptance of ambiguity, as the promise and the willingness to continue to question, and to ask, and to wonder, and to disrupt?

Rather than concluding, I resist conclusion following Koro-Ljungberg (2010): "Instead, unpredictable attentiveness and unexpected relationship with the Other could activate researchers' responsibility and thus enable open and humble data interpretations, as well as study conclusions that avoid definite closure" (p. 608). I question and question and question. In what ways do experience and "truth" interact as I take up teaching—and researching the teaching of—mathematics? How does my distance from a particular construction of a number influence how I read that number and its truth? How does bias impact what I doubt and what I believe? In what ways does the mathematics I "know" interact with these biases? What happens when faced with a problem with multiple or conflicting truths? Do the ethics or politics drive the solution? The

mathematics? What, or who, wins? By asking these and similar questions and remaining ambiguous in our understanding of how they might be answered, perhaps we can begin to answer Neyland's (2004) call to "reenchant" mathematics and mathematics education.

Dust Piles in Intra-action: A Non-Concluding Conclusion

At the end of the interview, Ayesha and I packed up our bags. She got her computer, several books, and folders. The sun had set while we were talking, and the room was quite dark. It was almost six o'clock. She and I walked down the hall together. The custodians had been working while we were speaking. There were six piles gathered in the middle of the hall, dust and broken pencils, and scraps of paper. Traces of the day. They would be forgotten by tomorrow. We oriented our bodies around them, shifting our trajectories, adjusting, negotiating. The lights were on down the hall and in the offices at the end of the hall.

> We are responsible for the world in which we live,
> not because it is an arbitrary construction of our choosing,
> but because it is sedimented out of particular practices
> that we have a role in shaping.
>
> – Barad, 2007, p. 203

Sedimentary, cemented, layered rock built upon who came before us.
Made of bits and pieces, scraps of knowledge.
A ribbon of pink
Upon a swath of brown
Perhaps there is a body buried there
Its imprint recognizable
Waiting to be discovered and recognized for what it is
Perhaps, yet again
It waits for the freezing temperatures, the crack
The rain
To expand and break it bit by bit,
So, it can make its way back to the sea
And swirl
Uncertain of where it
might
end
up.

CODA

> The open-ended nature of the future, its capacity to deviate from the present and its forms of domination and normalization, necessarily link an ethics, how one is to live, with a politics, how collectives, and their constituents are to live and act together and within what protective and limiting parameters.
>
> – Grosz, 2017, p. 2

This dissertation was/is concerned with the ethical and the political. In other words, I used it as a space to mark and consider my actions as a researcher and the fields within which I interact. I seemed to move between and back and forth between far-reaching and distant responsibilities to the field(s) and ever-present and intimate responsibilities to the more-than-human and human. These statements cannot quite capture my meaning, as this dissertation cannot quite capture it either. The meaning is between the lines.

Yet, these statements must be written and rewritten, and as I write and read and research and live, I continually contemplate how I came to and will continue to come to make decisions in responsibility to my participants (ethical moves) and how I aligned and will continue to align (or not) my work with the fields of mathematics education research, statistics education research, and qualitative inquiry (political moves). Although I separated out ethical as close and political as far, in thinking with Barad (2013), I also troubled these spatial arrangements and see the ethical and political as ever present and entangled within each phenomenon that was/is addressed in this dissertation. I contemplate the political/ethical in my wanderings as researcher in writing dissertation and coming into the field, and I draw attention to the political/ethical at work within the classrooms where I was in intra-action. The students in this study drew political/ethical into closeness as they deliberated how to make ethical decisions in light of political concerns.

The ethical and the political are not separable except through cuts that are enacted in intra-action with the spacetimematterings of which we are a part. The students in the course

grappled with serious and substantial topics such as race protests in Ferguson after Michael Brown's murder, the Ebola epidemic, and the European refugee crisis. Although at times these topics seemed distant from their daily interactions, upon scrutiny and study the events were pulled into closeness and their material effects were felt by the students. This pulling was felt even in a study on food that the teachers hoped would be less "heavy," the lines were drawn and stretched between corporations that produce and market food and the students' food choices. Despite the teachers' best attempts to have a unit that was not controversial, political questions could not be escaped. In each unit the ethical and political, at first seeming far apart, became interwoven.

Within my research practices the ethical and political were entangled as well. I read and researched methodologies and ways of knowing. I considered how to be in the field and learned the rules for interacting with participants, yet in my day to day decisions ethical questions arose anew and with new significance. I could learn a procedure for an interview that fit with the conventions of the field, yet it would fall apart when I entered the field, as it was pulled into closeness with ethical considerations in its enactment. I wondered at the conventions of research methodologies as I wondered about the conventions of mathematics classrooms.

Donna Haraway (2016) draws our attention to thinking about how we might live and die together well. That is the so what of this dissertation—how do we live and die together well, in research institutions and through research practices, how do we live and die together well in mathematics classrooms, and in relation to our communities and in relation to issues that might at first take seem to be outside the realm of our interest or control. In thinking with Haraway, and with the curriculum of the course and with the fields in which I was intra-acting, I began to wonder how data interacts with our lives and how we use it to live and die together well.

I wondered how the ways that I produced data and the ways that I put data to use in specific material arrangements mattered for the ways that the fields within which I was and am acting become. As I moved between qualitative inquiry and statistics education and mathematics education research, I also wondered how the representations (chapters, manuscripts, transcriptions, collages, tables, research presentations) that were produced from the data might be taken up and what conclusions might be drawn from them. What would people think of the participants and their classrooms? How can I present the study in ways that did the students, teachers, classroom, and curriculum justice knowing that I can never get it right? How can I enact the study in ways that do them justice while I am in their direct presence?

In both personal and political decisions, data is often used as a means toward a decision or an accounting of what is true and known. Lists are made, surveys are consulted. I look at the number of reviewers and the average number of stars for each purchase on Amazon, and I go forward with my decision believing that the spatula really will be wonderful. Data permeates our lives and determines futures. Data is irresistible because of the confidence it affords and the distance it can create between me and the decision. I can use it to know for certain, and I do not have to occupy the grey area for long… Yet, this certainty is an illusion as variability is omnipresent. The possibilities for data's becomings are indeterminate. The possibilities for radical reconfiguration are far reaching.

As Grosz's (2017) statement at the beginning of this section attests, the future is open-ended and both the personal and the collective moves matter in its ongoing reconfiguration. Differences in knowledge making practices are of concern in both the ethical and the political domains. The ways that fields discipline and determine what counts as legitimate knowledge within them and the ways that educational researchers live within these fields matter.

In this dissertation, I constructed two knowledge making apparatus and attempted to account for how data is enacted as a part of knowledge making apparatus. I do not take up the data as sterile and neutral nor do I imagine it as independently agential. Barad's (2007) objectivity depends on a detailed accounting of the specific material arrangements of knowledge making apparatus. The data is a part of the phenomenon that is this dissertation and simultaneously part of the diffractive apparatus within it.

In this dissertation, I have made moves from which lines can be drawn out to ethical and political concerns. I have aligned myself at times through this product with the conventions of particular fields (mathematics education research, qualitative inquiry, statistics education research) and at other times distanced myself. These decisions were not taken lightly. This dissertation is data for my becoming as researcher, and the decisions I made to align or distance myself from fields and conventions will be taken up as evidence of my ability to do science in the academy.

I want to return for a moment to the spacetimemattering of the comps meeting with which I began this dissertation. As I entered the meeting, I hung all my writings under self-portraits drawn during the transcriptions of my interviews. I considered who I was in responsibility to my participants and to my field. I pinned trace paper over the portraits and the writings, the evidence of who I am/was in that spacetimemattering (see Figure 37). I asked then–

What am I becoming?

When does a scholar become a scholar?

What am I producing? How is it producing me?

How is this production being assembled?

What intra-actions matter in it?

Do I want to be a scholar? In assemblage with what?

What happens when you write about math?

When does math become math?

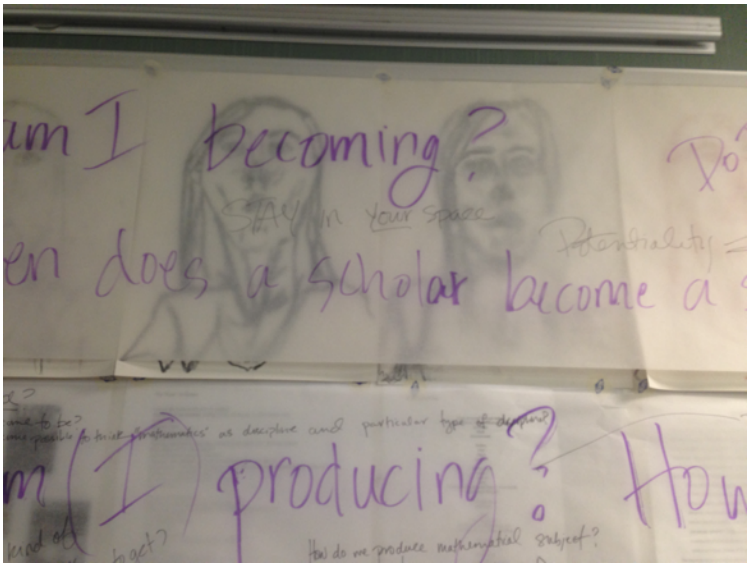

Figure 37. Self-portraits and tracing paper.

This meeting happened months before, maybe a year even before I started my comprehensive exams that would "prove" I was ready to start a dissertation. And I am in this here/now spacetimemattering with the same questions.

Perhaps as I continue to think these questions—they are ethical questions that affect my becoming—I am made through the iterative asking and re asking, turning them over and re-turning them in different configurations to see what difference it makes. As I move forward and backward and turn return and compost these questions, I take them up with other concepts. What possibilities are yet to be enacted that might matter for how we live and die together well? Can we perpetually (re)turn, making new figures and shapes to see what difference they make in the world?

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APPENDICES

Appendix A: Interview Guide from Original Study

Project Summary:
The goal of the case study is to explore differences in how novice and veteran mathematics teachers perceive mathematics curriculum development and student involvement. This study will compare the perceptions and beliefs of a first-year teacher and a veteran mathematics teacher as they work together to plan and implement a 12-week middle grades mathematics course. The course is student interest led and uses mathematics as a tool to understand and analyze current events and topics of interest to the students.

Purpose: The purpose of this study is to examine how and why teachers and students negotiate a mathematics curriculum. Specifically, this study will ask the following questions: 1) Why would a teacher engage students in constructing curriculum? 2) How do teacher beliefs about mathematics change through interactions with students? 3) How are the teachers' beliefs related to her dispositions and actions in the classroom?

Interview Guide for Teachers:

1. Teacher's purpose, beliefs and perceptions about the course.
    a. Tell me a little about the course you are teaching.
        i. Probes:
            1. You mentioned …can you tell me more about that?
            2. You used the word _____, can you define that for me?
            3. Can you give an example of what ___ might look like?
        ii. Follow ups:
            1. Tell me how you create your course.
                a. How were the topics of study determined for the course?
                b. In designing your course, what experiences stand out to you that informed your decisions?
                c. How do you decide on the direction of the course from week to week and day to day?
            2. What hopes do you have for the course?
            3. What concerns or fears do you have as you begin the course?

2. Teacher's purpose, beliefs and perceptions about the mathematics.
    a. What is the role of mathematics in your course?
        i. Probes:
            1. You mentioned …can you tell me more about that?
            2. You used the word _____, can you define that for me?
            3. Can you give an example of what _____might look like?
        ii. Follow ups:
            1. How do you use mathematics in the course?
            2. What is the purpose of teaching mathematics to students?
            3. What role do you think mathematics should play in students' lives?
            4. Can you describe a time that you think mathematics can be helpful in society?

5. Can you describe an instance when you think mathematics is not helpful in society?

3. Teacher's purpose, beliefs and perceptions about students.
    a. Tell me about the students in the class.
        i. Probes:
            1. You mentioned …can you tell me more about that?
            2. You used the word _____, can you define that for me?
            3. Can you give an example of what _____ might look like?
        ii. Follow ups:
            1. How would you describe the role of a teacher?
            2. How would you describe the role of a student?
            3. What might you do if a student doesn't understand?
            4. Is it ok to be uncertain in mathematics classrooms, why or why not?
            5. How do you decide when to intervene with a student or the class and when to allow them to progress on their own?
            6. What do you hope that the students will take away from the course?

Appendix B: New Horizons Mission Student Work Sample

NEW HORIZONS

1. **Describe:** What did you notice in the video? (What did you see?)

A rocketship that flew to a new planet. Someones face. Lots of Stars and Space.

2. **Interpret:** What is happening?

a. *Explain* what I see

I see something flying over a planet. Crashed into Jupiter.

b. Tell about my new insights.

I think the sent something out to see something

c. Find connections with other learning.

I think someone died

3. **Evaluate:** What is my opinion about this? or What is the value of it? Why do I think this? (Make judgements that are clearly connected to observations I have made.)

I think that this video is important to show people things outside of earth.

4. **Plan:** In what ways could this insight be useful to me in classes, at home, in my life in general?

Now I can be aware of the surrounding planets and what things have been discovered or come from.

5. **Questions**: What questions does this raise for me? (List as many as possible)
   a. Consider what you know about Pluto
   b. Consider what you know about NASA
   c. Consider what you know about speed and travel
   d. Consider recent news about the New Horizons Space Probe

What exactly is pluto made of? Is it a gas? Have astronauts gone to pluto? Did nasa send rovers to pluto? How fast did the air craft travel? and how long did it take? and did it need lots of fuel? or just energy? Why have they excluded pluto as a planet? What makes pluto a "Dwarf" planet? Is there any type of life on pluto? What facts do we know about whats actually on pluto? Is there an edge to space? What color is Pluto?

NEW HORIZONS

"The teams had to hone the New Horizons spacecraft's 3 billion-mile flight trajectory to fit inside a rectangular flyby delivery zone measuring only 300 kilometers by 150 kilometers." - *How NASA Got New Horizon to Pluto* by Bruce Dorminey, Forbes Tech - 8/9/2015

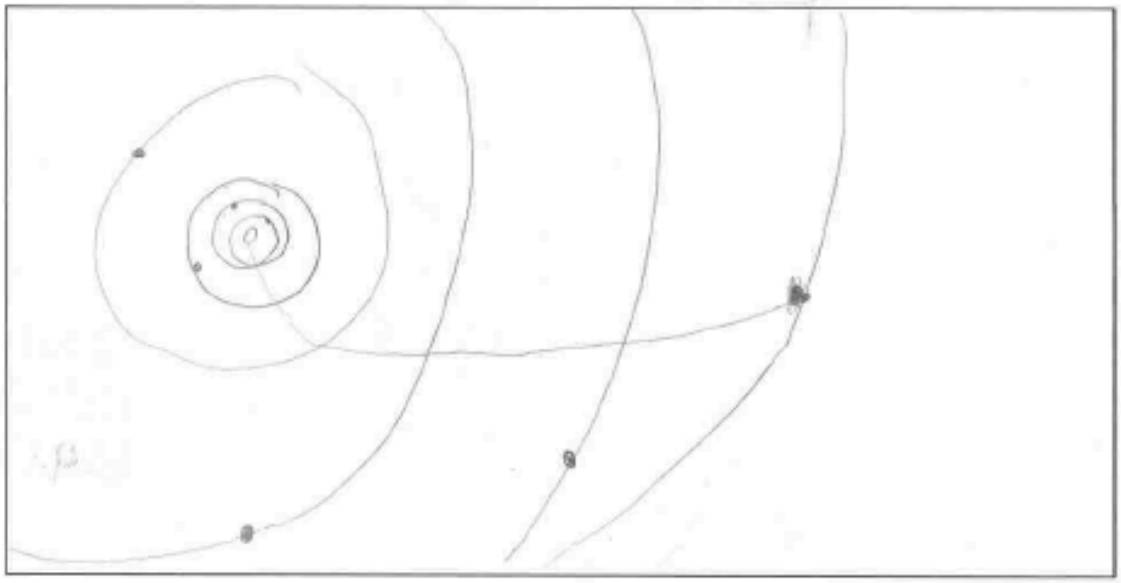
A. What is a trajectory?

The path followed by an object moving under the action of given forces

B. How do you think NASA determined this trajectory?

With simulators, tests, and some of the information from former trips in space.

C. Draw what you remember the trajectory looked like in the video:



5256 [redacted]
÷
365

what was difference in speed
A − B
=
find out speed from Jupiter to Pluto

1424 minutes in a day
365 | 525600
365
1606
730
8760
8760
00

5125
−365
160

365
+365
730
+365
1095
+365
1460
+365
1825
+365

365
× 24

1285.2
× 0.62
25704
771120
746.824 MPH

1285.2
× .62
25704
771120
746824

583200 minutes

10
×10
100

5,832,000
×1000

482 [illegible]
4.82112 × 10⁶

Possibilities
1.02 105
1029.63 KM/min

1008.23 Km/min

21
×60
00
1260
1260
21.something

21.42
× 60

1285.20
→ 771126
1285.20
× .62

D. What information would you need to calculate the rate at which the New Horizon space probe is traveling?

The distance, what type of probe we are using, how much oil/gas you would need, speed of probe, Direction, locati

E. If your calculator couldn't show all the numbers, what technique could you use to calculate using these large numbers?

Scientific Notation

NOTES:

Rate - A fixed number

Distance from Earth to Jupiter = 588,000,000 Kilometers

Distance from Jupiter to Pluto = 4.5,000,000,000
4.5 billion Kilometers

New Horizons left Earth on = January 19, 2006

Approached Jupiter = February 28, 2007

Reached Pluto = July 14, 2015

2920
+ 136
3056

8 yrs 5 months 14 days

Distance over time

Distance / time

Divide

Will get rate!!!

365 + 40 = 405

12 + 28 = 40

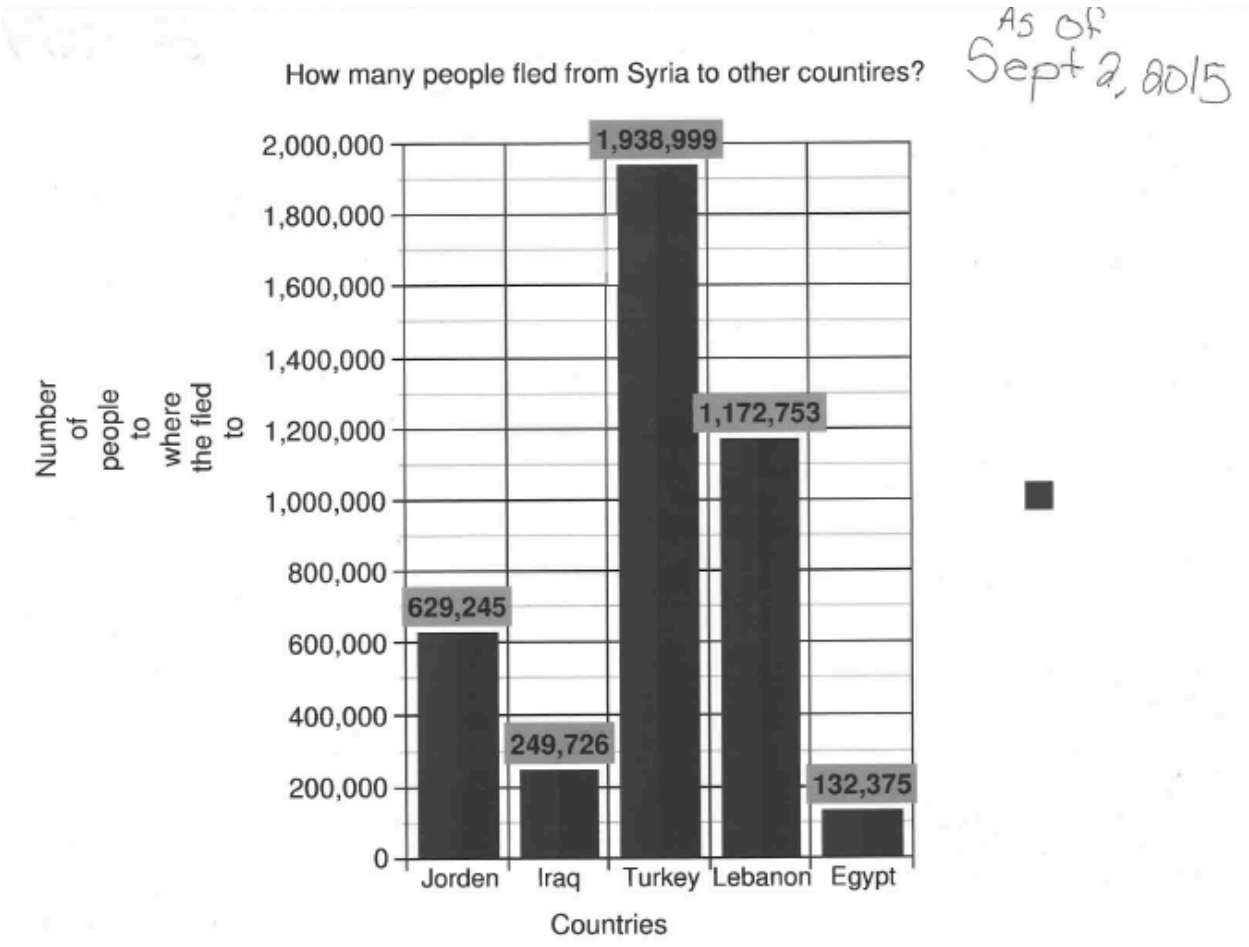
28 − 14 = 14

3285

2,920

31 + 30 = 61

Appendix C: European Refugee Crisis Student Work Sample



European Refugee Crisis

1. **Describe:** What did you notice in the pictures? (What did you see?)

In the picture I saw two women and three children walking. There were also bunches of tents

2. **Interpret:** What is happening?

a. *Explain* what I see

I see that there are two women walking with kids and groceries in front of tents

b. Tell about my new insights.

I think the lady with the groceries is holding her sons hand and the the other lady is linked with her kids

c. Find connections with other learning.

I think some organization has came to there country to give them refuge

3. **Evaluate:** What is my opinion about this? or What is the value of it? Why do I think this? (Make judgements that are clearly connected to observations I have made.)

My opinion is that there are alot of unneascary struggling people when we could help. To show people in everyday struggle. Because thats my feeling on what I see in the picture!

4. **Plan:** In what ways could this insight be useful to me in classes, at home, in my life in general?

This might be useful for me to know what is happening in other places in the world and to appreciate the life I have more

5. **Questions**: What questions does this raise for me? (List as many as possible)
   a. Consider what you know about the word Refugee - write the definition
   b. Consider what you know about Asia - Middle East - Africa
   c. Consider what you know about Conflicts
   d. Consider recent news about Europe - EU - United Nations

- Where are they?
- Are they a family?
- Are those there own tents?
- Is an organization providing them this shelter?
- Is it hot in those outfits?
- Where are they going?
- Where are they coming from?

10. Look at the graph in front of you. What do you notice?

I noticed it has a positive correlation

11. Interpret - what do you think the graph(s) is/are about?

It could possibly be population each 10 years

12. Are you able to label the graph?

Yes

13. What questions do you have about the graph(s)?

none

European Refugee Crisis: Creating My Data Visualization

You will be gathering data and making your own visualization of that data. This visualization should show: refugee figures from 2014, 2015, and 2016 represented as proportions of the total human population of Earth (you will need to predict using information that you have, through logical reasoning)

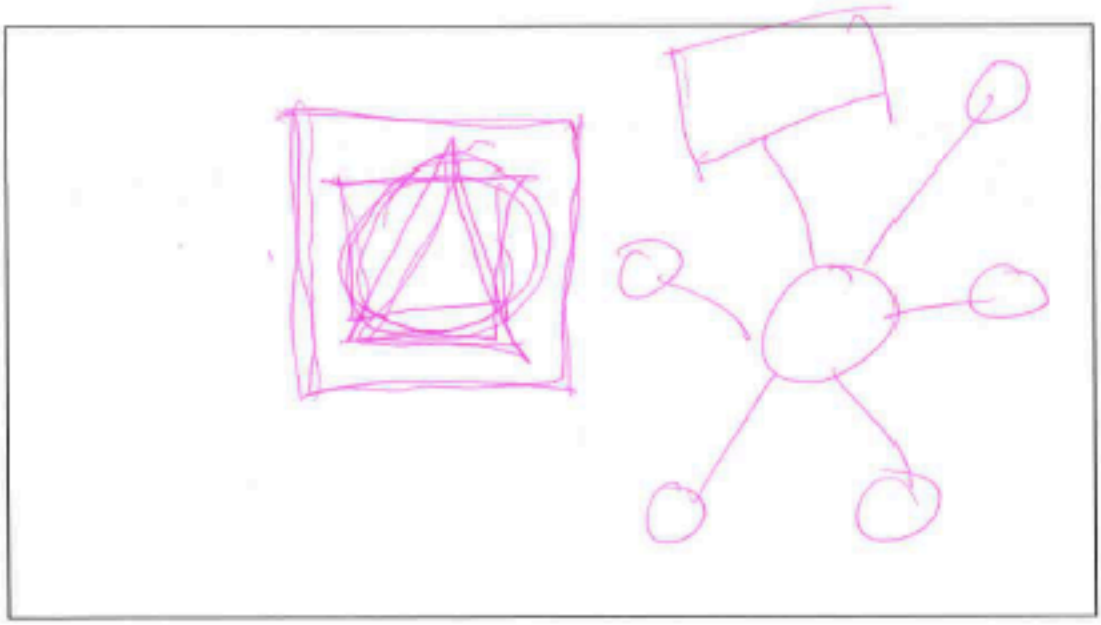
14. What data do you think you need to create your own infographic about the refugee crisis?

the number of refugees figures from 2014, 2015, 2016. Also the proportions of ~~the~~ all the human population.

15. What ideas do you have about creating your own visual data?

That we going to use some type of shape design like with a square.

16. Make a rough sketch of what your idea would look like? (no data points necessary for sketch)



17. What is the population of refugees/displaced persons on Earth? (2014)

19.5 million

18. What is the human population of Earth? (2014)

7-10 billion

19. Show/calculate the relationship between refugees/displaced persons to total human population (2014):

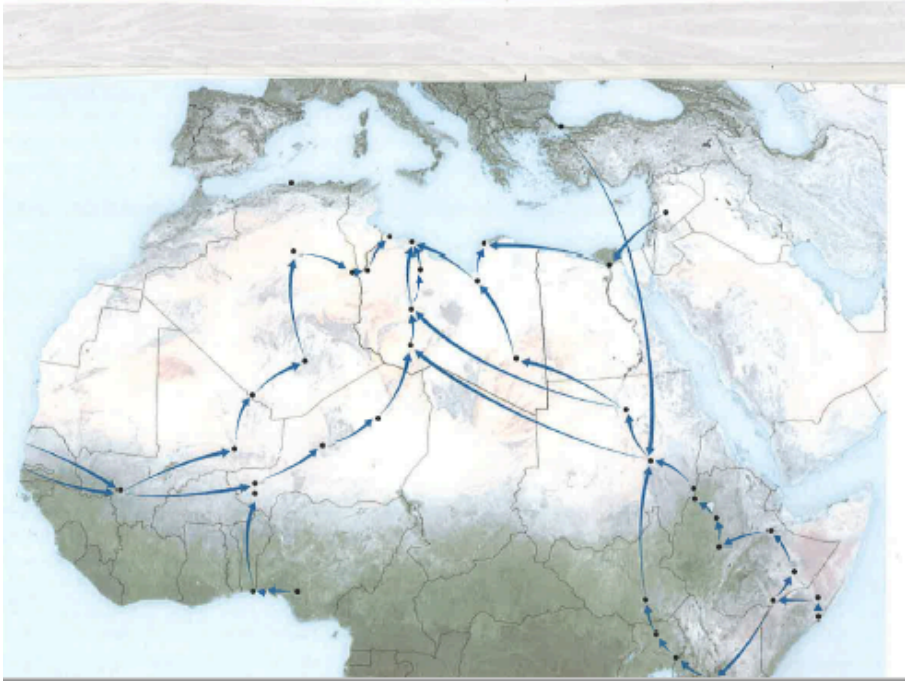
19.5 mil. of 2014
7-10 bil.

20. How can we find out data for 2015 and 2016?

By researching answers

21. What information would you need and where would you look?

You might look with UNHCR and population and number of refugees



Appendix D: TBI in NFL Student Work Sample

Current Events AGP: Sports Math

1. **Describe:** What did you notice? (No judgement: What did the articles say?)

I noticed that in all four articles that football players are getting injured and even killed in games.

2. **Interpret:** What is happening?

a. Explain what I see Football players are getting tackled that they have a blood loss or they get injured if another player accidentally kicks the player in the head.

b. Tell about my new insights. I now know that football players are still getting injured in games and players are taking head blows that are getting killed.

c. Find connections with other learning.

On the news a referee used racial slurs at football players.

Current Events AGP: Sports Math

6. **Describe:** What did you notice in the video?

I see people geting hit in the head multibal times and then people who cant remember 6 numbers. I see people with CTE

7. **Interpret**: What is think is happening?

I ~~think~~ that The football players are geting injered too much and the kids and adults are in great risk.

8. **New Insights**: What you didn't know before?

Before I didnt know much abaut football and how dangerouse it is and now I know that it can be dangerouse and how bad and what can happen.

9. **Questions**: What questions arise after watching the video?

On avarage, how many people out of football players get CTE? What ~~happened~~ happens to the brain, do they die or rot completly in places or all over?

10. **Plan**: What can you solve?

I will not play football and advise others not to play and will not let my kids play.

11. **Discuss the positions below. If there is a football player, or someone familiar with the game in your group, ask them to explain the job of each player**

12. Predicting. Looking at the data below, which position do you predict will have the highest risk of TBI? Why?

Kick off because they get on the field the most.

13. **Complete the data table below.**

Data Table: 1994-2001 NFL research of mild traumatic brain injuries

Offensive/ Defensive	Position	No. of case	total cases	% incidence of TBI	no. of game positions	% of injury per times on the field. Risk
Offence	Quarterback	62	784	7.9%	3826	1.62%
Offence	Running Back	69	784	8.8%	7652	.9%
Offence	Wide Receiver	94	790	11.8%	7652	1.2%
Defense	Linebacker	52	788	6.5%	11478	.45%
Defense	Secondary	143	786	18.19%	15304	0.93%
Defense	Defensive Line	67	788	8.5%	15304	.43%
Special Team	Kick Unit	131	789	16.6%	38260	.34%

TBI - traumatic brain injuries

14. What does the **incidence rate** tell you about specific player position?

It tells you the percitage of getting tbi with the position you play.

15. What does the **risk** column tell you about each player position?

It tells us the percitage of injury per times on the field with the position you play.

Work independently to answer the following question and complete the ranking

16. Which percent would you use to rank the risk of Traumatic Brain Injury? Why?

Probably the risk column, because it gives the percitage of getting a injury on the field instead of the probability of getting tbi.

17. Order the positions from greatest to least risk for TBI

1. Quaterback - 1.62%
2. Wide receiver - 1.2%
3. Defense secondary - 0.93%
4. Running back - .9%
5. Linebacker - .45%
6. Defensive line - .43%
7. kick unit - .34%

18. Compare your ranking with someone else. Did you agree or disagree? If you disagreed, tell why?

We agreed with each others answers.

Appendix E: Sugar in Food

Food

1. **Describe:** What did you notice in the pictures? (What did you see?)

That each picture included a table with a supply of food.

2. **Interpret:** What is happening?
   a. *Explain* what I see

I see people taking a picture with food.

   b. Tell about my new insights.

I wonder if the food is something important.

   c. Find connections with other learning.

About people and there food in/ from other countrys

3. **Evaluate:** What is my opinion about this? or What is the value of it? Why do I think this? (Make judgements that are clearly connected to observations I have made.)

I think that the pictures are interesting because it shows people and there food with/ from different backgrounds.

4. **Plan:** In what ways could this insight be useful to me in classes, at home, in my life in general?

I'd tell or show me about other people and there food in/ from different places.

5. **Questions**: What questions does this raise for me? (List as many as possible)
   a. Consider what you know about hunger
   b. Consider what types of food you eat
   c. Consider what you know about your daily intake
   d. Consider recent news about which food is good or bad

- I wonder why the photo was taken?
- where did it come from?
- Why was the photo taken?
- Where was the photo taken?
- Who is in the photo?
- What kind of food is it?
- Where did the food come from?
- Is the food important?

6. What is a calorie?

Unit of measurement. It is equivalent to the amount of energy it takes to heat one kilogram of water to increase in one degree

7. **Find your Basic Metabolic Rate (BMR)**: Your BMR is the calories you need just to survive. Your BMR varies based on your gender, height, weight and age.

Step 1: Find your weight in kilograms. Divide your weight in pounds by 2.2.

$2.2\overline{)114}$ $51.\overline{81}$

$51.\overline{81}$

Step 2: Find your height in centimeters. Multiply your height in inches by 2.54.

$2.54 \times 68 = 172.72$

172.72

Step 3 for **men**: Use the basic formula to calculate your BMR:
66 + (13.7 x weight in kilograms) + (5 x height in centimeters) – (6.8 x age in years).

$66+(709.797)+(863.6)-(81.6)$

$775.797+(863.6)-(81.6)$

$1,639.397-(81.6)$

$= 1557.797$

Step 3 for **women**: Use the basic formula to calculate your BMR:
655 + (9.6 x weight in kilograms) + (1.8 x height in centimeters) – (4.7 x ages in years).

Current Events Math AGP - Food

8. Describe: What did you notice in the videos? (What did you see?)

- 2 different opinions
- lots of different food considered both swept and not swept.
- ~~lots of~~ sugar vs fat

9. Interpret: What message do you think the videos were trying to convey?

one side ~~that~~ says that sugar is the issue, another says that as long as it's incorporated into a healthy diet it's fine.

10. Evaluate: What is my opinion about this? or What is the value of it? Why do I think this?

I don't know what I think about this, because I don't know enough about anything to say that sugar is so bad.

11. Plan: In what ways could this information be useful to me in classes, at home, in my life in general?

Interesting how so much sugar is in what under my nose.

Current Events Math AGP - Food

How much sugar is okay each day? The World Health Organization (WHO) says 25 grams per day.

1. How many grams of sugar are in one teaspoon? Use the scale to measure one teaspoon of sugar.

4 grams of sugar equals one teaspoon

2. How many calories are in one teaspoon of sugar? One gram contains 4 calories.

16 calories per one teaspoon

3. How many teaspoons of sugar can you eat per day according to the WHO?

6 teaspoons

3 1/2 x 6 = 96

4. How many calories of sugar does the WHO recommend per day?

100 calories

So, what does this mean for Halloween?

5. Find the grams of sugar in some of your favorite candies.

Candy type	Grams of Sugar	# of pieces I could eat that equal 25 grams or less
Almond Joy	8g	3 pieces
Reese's	23g	5 pieces
Reese's pieces	22g	3 pouches
kit kat	21g	5 pieces
Hershey's	24g	6 pieces

6. Write an equation to show the candy you would consume on Halloween, if you limited yourself to 25 grams, and only had your favorites (from the table above). Use variables for each type of candy to represent the grams of sugar.

$25 > g \cdot x \qquad 25 > 21 \cdot 1$

g = amount of grams of sugar in the candy x = amount of servings you can have

7. Write an equation to show the candy you would consume on Halloween, if you were NOT going to limit yourself to 25 grams.

$100 > 21 \cdot 4 = 100 > 84$ y = amount of servings you have

$x \geq g \cdot y$ x = total grams g = amount of grams of sugar in the candy

8. If this was the only sugar you allowed yourself to eat each day around halloween, what else would you have to cut out of your diet? (cereal with sugar, jam, juice, etc.) Pop tarts, Ice cream, Ice tea, etc

9. If there is candy you don't particularly like, would it be worth eating it? Why or why not?

No because you don't like the candy so it is pointless eating.

10. What can you do with candy you don't want to eat? Is it okay to throw it away? Why or Why not?

Give it to someone or throw it away. Yeah it is okay to throw because the people who buy the candy know that not every one is going to like the candy.

Tomorrow we will look at who benefits from your consumption of sugar at halloween.

Appendix E: Air Pollution in China Student Work Sample

1. **Describe:** What did you notice? (No judgement: What do you see? What did the article say?)

China makes wierd things that are very industrial, which pollutes the air. Most of the bad pollution comes from the worlds eastern hemisphere.

2. **Interpret:** What is happening?
   a. *Explain* what I see

I can see that dark blue would be the least to dark red being the most. All pollution in one line

   b. Tell about my new insights.

That America has like no air pollution. That 90% of the 360 cities, failed to meet air quality standards

   c. Find connections with other learning.

Too many factories, and life reuning, devastation.

3. **Evaluate:** What is my opinion about this? or What is the value of it? Why do I think this? (Make judgements that are clearly connected to observations I have made.)

China should spread buissness or lower rate of production.

4. **Plan:** In what ways could this insight be useful to me in classes, at home, in my life in general?

It could tell me about some of the issues in those countries if I want to travel there.

5. **Questions**: What questions does this raise for me? (List as many as possible)
   a. Consider what you know about air pollution
   b. Consider what you know about Atlanta's air quality
   c. Consider what you already know about China
   d. Consider recent news about China

Why doesnt China shut down some factories, although it makes money its killing there people. If the people of China die there will be no one to work in the factories. I think China should spread there factories around, but all the other countries who have good air like America probably wont want to have factories around that give off a bad air.

Look back at the article: *Air pollution kills over 4,000 every day in China*. How many people die in a year from air pollution in China? 1,460,000

A. The daily number I am using is: 4,000

B. How many people die in **one year** as a result of air pollution?

Show your work
4,000 × 365 = 20000 + 240000 + 1200000 = 1,460,000

C. How many people die in **ten years** as a result of air pollution?

Show your work
14,600,000

D. What is the difference between the three group's numbers? Difference

Show your work	4400	4500
4000 study: 1,460,000	−245,000	−192,500
4400 study: 1,606,000		

4500: 1,642,500

1,606,000 − 1460000 = 245

1,460,000 − … = 192500

E. What impact did rounding have over one day?

400 people were left out which means the total number was smaller.

F. What impact did rounding have over one year?

245,000 people were left out.

G. What impact did rounding have over 10 years?

2,450,000 people were left out.

H. What if we predicted a 20 year death rate? What impact would rounding have? 245

4,900,000 people would be left out.

I. When might you use rounding? Why?

You'd use rounding to

- make it better on our eyes, to turn it into a number people like
- To simplify something
- To exaggerate or make a point.

J. When would you not want to use rounding? Why?

When you are using facts, because then the fact would no longer be a fact.

K. If China's current population is approximately 1,403,105,000 what fraction of China's population will die of air pollution related illnesses this year?

Show the fraction

$\frac{14,600,000}{1,403,105,000}$

L. How could you make that fraction into a statistic that is easier to understand?

1,460,000 / 1,403,105,000 of chinas Population dies each year from air polution. Turn it into a percent.

M. Use what you decided in (K) above, to create a more understandable number.

Show your work

$\frac{1460000}{1403105000} =$

Around .104%

Appendix F: Ayesha's Story

I'm a third-generation non-refugee because my grandfather walked all the way to Pakistan from India. He found refuge in Pakistan in 1947 in the largest human migration ever recorded.

He walked from India to Pakistan with his family and with my father in his hands.

My father was born in India.

I was born in Pakistan.
I was the first person born in Pakistan,
It meant a lot to me, I guess, to say that—yeah, my family found refuge in Pakistan

Refugees were middle class people just like my family. My grandfather had graduated from University in India. He was an engineer. My father was an engineer here. And, they are just regular middle-class people.

So, I think when I told… I didn't tell them exactly all of this. I just told my kids I need to tell you where I am coming from because I feel like this could be a bias, and I want you to know it.

Which is that I am—I didn't think of myself this way until I read the story— was that I was a refugee in Pakistan, and I just happen to be an American because my father got an American citizenship here in the 70s.

My grandparents had to fight to come to Pakistan in 1947, so in that way I didn't do any of the fighting. People before me did, but I am first generation non-refugee in Pakistan and from a refugee family.

Appendix G: Poetic Field Notes in Excess

Field Notes – October 26th – Monday 10:50–11:20 in classroom 11:20–12:08 in building Ayesha's classroom, Final composition at Drip Monday 12:45–2:00

Late late late
Caffeine
Heart racing
Rain and puddles
Don't pass stay in your lane
Be prudent
Don't rush.

Here
Not too late
Smile smile smile
Its mark
Id seen that he was in Stanford for the weekend and joke
About how he is awake now
Barely he says and heads upstairs

On down the hall to follow the procedure to sign in and be counted as present
Cornelia says, I looked at the camera and said oh its just Susan.
I guess I have achieved the goal of the participant
I am no longer a disturbance
Just another wave in the ocean bobbing the cork

Why the recoil from disturbance?
Can I be the pregnant woman boggy boarding on in a bikini 8 months pregnant
Drawing stares
Surprising
Or must I stay hidden beneath my mui mui
The first is more fun, I should know
Is it more or less responsible?
To whom to what to when

What the fuck were you thinking student one to student two
What did you say? I couldn't hear you? With a smile, is that the right kind of disturbance
the judging the I caught you in the act
I think not

On up the stairs
Late late
Shame
Will I be
Counted
As tardy
The room is dark and quiet

A movie on the screen
Teacher standing at the back waves me in
Welcomes me?
I slid in and shut the door loudly
Accidently
Disturbed and disrupted
A student walks toward the door her arms full of laptop I open the door again for
Her
She smiles
I stand by the door
Awkward to take notes like this
The dark is welcome though and allows me to hide

Sugar
Dopamine
Sex triggering reward
Sugar behaves like a drug rewarding
Experts talk about what they know
I see a boy look across the table and smile at his friend
A teenage response to sex
And drugs

Now im not being objective judging just crept in—why the teenager, what assumptions prejudices am I showing toward them. How do I believe how they are portrayed in media?
Maybe it was just a
Smile

The first movie ends
Kids don't try this at home one student says
Laughter and giggles

Movie two blond blue-eyed woman
Tells the evils of sugar where it lurks
And
Who is hiding it there?
Secrets of Sugar
26 t of sugar a day
20 bags of sugar a year
Student, it's a conspiracy
What makes us crave
The bliss point

What is the bliss point of a researcher?
The amount of data you need to stay valid
If I increase data does it become more valid
Is there a breaking point?
What is the counter to data?

The fat to its sugar
Goldilocks needs the perfect amount and
We'll keep coming back for
More

I sit on the floor against the wall by the door
Looking up at the students' faces
And
Over at the screen
Watching them watch her
Her looking back
Convincingly
Persuasively
Using data
To
Create
Truth for them, for me

The students seem to suspect that these movies are meant to teach them something
There is a tension rising in the air.
the second movie starts
chatter ensues and is quickly brought back down

Bellies bulging over belts,
Close ups of waistlines
What feeling does this evoke for me for them
Are we supposed to hate these people, pity them?
Want to avoid becoming them.
What is the use of that image there?
There are some snickers and then
One student wonders aloud, did they have permission to show them?

I'm going to stop this now
Screen freezes 11 minutes in
Now use this space to reflect

I rise turn on the light hesitantly, does she want it on? Am I being helpful?
I move to a student desk and sit. She comes to give me a half hug and hello
How are you
Good and you
Wow it's a lot
Yeah, I need to eat less sugar

after the quiet writing
students are serious and intent
she moves to noticing

Ok guys well start with a round of noticing

(I reflect, what are the practices that promote Caputo's event-individual thinking noticing reflecting, is it opportunity for reflection or forced reflection does it matter?

I saw scales about how much sugar we eat
Some people are protesting against sugar
They are talking about sugar and being hypersensitive
Is that, how did you know? What did you notice?
Sugar is in every processed food.
Noticing is a direct observation kind of like in science lab
reminder that noticing is just what we see think of it like
scientific observation
no judgment
this rings bells for me – my own questions from the morning how do we see
objectively subjectively
with feeling without

I saw a lot of sugar and a graph of how levels went up through the years
The graph showed an increase in obesity
Some people talked about effects of sugar
Sugar causes damage to the liver
A lot of talk about how sugar can be addictive
Videos about sugar and how bad things are, things I thought were ok have sugar
There are different scales of sugar
Sugar is in unlikely products
Initially people thought fat caused obesity, now they know its sugar

I can already feel that this is a very sensitive topic. When Elisabeth and I thought about this topic we didn't think how we felt (hiding away emotion, feelings) we felt we were objective
Think of it as a researcher
There are two sides
Don't have to agree
Reflect how do you feel?

You were all born in the 2000s, in the 80s and 90s there was a push against
Fat
Now you notice different products in the store that are fat free or 1%

This is what Drs. are saying now. Dr. Lusky the endocrinologist shows how sugar affects people obese or not

I gave you a task to do over the weekend.
Im going to show my picture.
It was huge for us to see how much we were eating

then the teacher shows the image of herself and her food from Saturday
she says first don't judge me
then catches herself and says well go ahead and judge its okay
she has talked about this before allowing herself to be judged as an example

Appendix H: Excess Data

Because it's sort of scary to approach something politically, potentially volatile and I remember thinking with the LAP project like Ebola was not politically like everyone wanted to know what was going on. I mean we could look at the biology of it we could look at the math of it and then we could begin to look at the funding and inequity and that stuff. The Ferguson the Michael Brown stuff when I brought that the kids said what's up with that let's talk about that and there was this moment in my heart where I just thought ew ahh ok (laughter) ok let's talk about that and of course the numbers that we looked at painted a false picture. That politics aside, the kids could say wow that looks like injustice in the math and in some ways it just took it out of the... What do you think? What do I think? Was this the wrong thing? Were they telling the truth? Were they not telling the truth? I think math has the it feels like math can do that for you sometimes like I think math can be manipulated and statistics can be manipulated whatever you want but especially around that issue. It felt like a good way to introduce kids to ok here's a talking point, what do you notice about these two graphs? I don't know well there are more black people than white people in that year but now there are more white people that black people in this year or whatever the case may be um. I'm not a confrontational person so if something feels like it's going to be confrontational, I'm much more likely to back off of it than to step into it I think that this…

Elisabeth 2-16-16

Susan: You talked earlier about race being socially constructed. Do you feel like race was something that was talked about a lot or you mentioned where people were from and what regions and some but was race something that was talked about or? Hannah: Race wasn't talked about in this LAP a lot but it is very hard for me to even talk about race because in America race is something that I don't even understand because race over here could be white and Christian could be your race. And race could be like race could be potentially, your religion your color and your culture all tied together in America. Nowhere else is this true, because you'll have an ethnicity and you'll have a culture which is different from ethnicity then you have a faith which is different from and them and so I like stayed away from that thing all together because I don't know...

(Ayesha photo elicitation)

So the thing about social studies was it just you know part of it was that current events are cool and we choose really cool topics, but I feel like it was the backbone or story to something and then it has everything connected. Like football a lot of people, a lot of the girls, were not even interested in football and I had at one point because they were complaining I said listen I'm not a football person I'm learning all these things and I did I learned all these positions that I never know and said you know what I am connected to is what is happening on the field and these boys are dying. And every week and every day actually there was boy that died, and we would open up an article about that boy and that's what got them was that connection and then they started to do the math. And then they started to do the statistics. What which player has the most chances of getting a concussion? Because of how much time they spend on the field playing and that was the only thing that they could connect to to do the math. I feel like social studies allows them to connect with what they were about to do, which math does not have that power for a lot of people.

Ayesha 2-4-16

That took easily 3 days of figuring out what was going on because there was a particular woman game developer who had been ... No, a critic of games, who was a woman, who had been threatened. Her life had been threatened and she had backed up several speaking engagements and it was a big thing in cultural media. The kids had seen it and were interested in it, and so that led us to looking at how women are portrayed ... Not only portrayed but how involved they are in the creation of games.

That was eye-opening because we had several gamers in the room who were like, "Oh, I've played that game, it's not that bad," and then when they actually look at the statistics of the numbers of women portrayed who are primary characters versus who were secondary characters versus who were being abused in some way in the game, it's like ... They were like, "Wow! That is awful. I didn't even realize when I was playing that game," but to get to the point where we had to look at the numbers again, about 2 or 3 day

The math can go on for ... Try and make the math about half because we'll often go into the next week and then we'll wrap up with a conversation, so probably 3 to 4 days of thinking about analyzing, talking and 2 to 3 days of actually doing math that then helps inform our final conversation about the situation.

Elisabeth 9-20-16

One of the things that happens periodically in current events math is you can compound a current event where the fundamental understanding of what's happening can be assessed mathematically. For example, the Ferguson, Missouri, Michael Brown's situation that happened in the fall of last year, you could look at what was happening in Ferguson, Missouri, there were riots.

You could ask the kids, "Why is that happening?" They would say, "Well, because, uh, a black man was shot by a police ... White police officer." That in itself would be reason for people to be upset but why did the riots continue? Why the riots continued was because there was a pervasive feeling, in Ferguson, Missouri, of injustice and inequality and mistrust. Elisabeth pre course

You can say that to somebody but when you have a classroom that was probably 30% African American students, 70% white students in terms of our Title 1 ... I don't know where kids were in terms of class but there was something ... Some kids could just get that and many kids, they could say it but understanding why, they didn't get it.

Susan: When you say, 'get that,' get what?

Some kids understood that if an African American person was perceived to be unjustly treated, that that would feel big. Other students might say, "Well, anybody treated unjustly is big," and so looking at the race issue in Ferguson, Missouri became a question of math actually. Why do some people feel like it's not fair or not equal and what we could do in Ferguson, Missouri is look at the population numbers, we could look at arrest records, we could looking at records of police stopping individuals.

Ferguson, Missouri kept track of those statistics by race. Over time, the kids, as we looked at these numbers and converted them to percents because that was the math that we were thinking about, could begin to see when we equalized numbers, we're not just looking at the number of people but we're looking at a number that's stabilized by percent, by having the same denominator, is what we talk about.

Kids began to say, "Oh, that's not ... That doesn't seem fair. If 70% of the people here ..." You know, if they only represent 30% of the community but 70% of them are being stopped, they began to see that there's an inequality there. Then you go back to the original question of why are there riots and kids can say, "Oh, because it really doesn't feel fair. Because out of 10

people, 7 of your friends have been stopped by the police, but if you're white, only 3 of your friends have been stopped by the police."

As a black person, you're like, "Hey, everybody gets stopped by the police," and as a white person, you're like, "Rarely do we get stopped by the police." That piece, that particular instance was getting at the core of why, aside from the emotional feeling, there was math behind it. There was math that could help kids understand how somebody who wasn't like them might feel.

Susan: Did you see students' reaction to that issue on Michael Brown change after you went through the math and how that-?

Yes. Oh, that was really interesting because it took us a couple of weeks of learning about the situation and asking them initially ... So, the first thing we do in this class with any issue is we do research. We start off by asking, "What do you already know about this?" and then kids get ... I provide them with some background information, just some reading, either an article or something from the internet that tells us about whatever the situation is.

They do reading and then they report out to each other and we try to debunk misconceptions in that very first part. There were initially some ... The misconceptions that were just in the media or out there and looking at the actual reporting helped us debunk some of those situations. Again, let me think if there's another situation. I'm thinking of Ebola. We worked on Ebola.

One of the misconceptions is this is the ... One of the things about the Ebola outbreak last year was that this is the worst Ebola outbreak ever. In terms of just quantitative, just the numbers of people, yes, it was. When we look at case fatality ratios, so we were looking at number of people who contradicted the disease versus number of people who actually died, the case fatality ratio showed a different scenario.

As we were looking, initially, at Ebola, we were finding out just how Ebola operates, kids had the sense of Ebola is deadly, anybody who gets it dies, it's the worst possible thing, they'd all seen the movie Outbreak in the media. Ebola, Ebola, it's just that this is the worst possible thing. Then you look at case fatality rates and you find that oh, only 43% of people die which is still a huge number of people, but it was really a different number from what they thought 97% of people died.

That math changed their perspective. In the Michael Brown situation, there was definitely a sense of, "Yeah, this doesn't seem right," but by the time we were done, you could ... I can remember one particular ... Can I say names? [redacted] got really interested in the numbers and actually stayed after the class several times because he was very curious about figuring out some of the ratios that we weren't doing in class, but he was aware that if you figured out these additional ratios, you would really see what the real problem was.

He stayed and he did that and in doing that, I think his eyes opened. He didn't come into it with his eyes closed but by the time he left, he was really clear like, "Wow! This ... If I lived in this place, I would just feel the inequality of it." For him, it really was different. I think when I surveyed the kids at the end, that was one of the current events that had the most meaning for them in terms of looking at it. If I had surveyed about that particular thing initially, I'm not sure where that would have gone but I think it was just in the news. They weren't tuned into what was really happening.

9-20-16 Elisabeth

Appendix I: Excess Acknowledgement[95]

ticandonga pencils.Bobcat.cabernet.Joe.modern folk playlist.Josephine.Antico Pizza.Cal.lemon pasta.Alesia.Doug.Dihema.Jay.Susan (the other one).Arches paper.Annie.daffodil bulbs.crutches.clean hair.ikea.dekalb farmer's market.tessa.skip.thumbprint cookies.smooth pens.scribbles in margins.staples.dust.binder clips.caroline's back porch.dean. Duncan .smartwool socks.hooded sweatshirts.lead holders.broom.Oakland Cemetary.new moon.Ulmer.Wolgemuth.Marn.Bohr.Kincaid.Mary.Tom.Meredith.Chuck.sneakers.sunglasses.poetry.Haraway.coffee.dancing goats.Denis.Drip.6th Floor.Beunos Dias Café.Ebrik.abandoned rolling office chair.porch swing.pansies.bird feeders.zoom.Nvivo.St. Pierre.pink and burgundy crocheted blanket.painted toes.violets.the smell of rose.mint tea.macbook air.endnote.hulu.marta train.pumpkin.

[95] This "text" was originally situated on my acknowledgement page at the beginning of the dissertation. I needed some help with formatting and reached out for help from an administrator in the college. He scrolled past this text and stopped, "Do you know that there is a bunch of gibberish on your acknowledgements page?" So here, I enact another cut and move this text where it might not make someone turn away from my dissertation and discount it, yet I think this acknowledgement matters as it accounts for more of the specific material arrangements of this writing.