Transcending the Conventional Science Curriculum: Supporting Students in the Negotiation of Meaning and Finding Their Place in Science

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TRANSCENDING THE CONVENTIONAL SCIENCE CURRICULUM:
SUPPORTING STUDENTS IN THE NEGOTIATION OF MEANING AND
FINDING THEIR PLACE IN SCIENCE

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ABSTRACT

TRANSCENDING THE CONVENTIONAL SCIENCE CURRICULUM: SUPPORTING STUDENTS IN NEGOTIATING MEANING AND FINDING THEIR PLACE IN SCIENCE

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Science education in schools is often inadvertently designed so that it is frequently inconsistent with students’ lived experiences (Aikenhead, 1996, 2001; Brickhouse & Potter, 2001). Science is therefore seen by students as an endeavor for someone else, contributing to a lack of access to the knowledge necessary to address scientific and environmental issues (Calabrese Barton, 2002; Fraser-Abder, Atwater, & Lee, 2006). This research promotes an exploration of meanings, allowing students to find their place in science and the roles that science fills for them. I assert that the consideration of humanistic approaches to science education provides the base necessary to transcend the uncritical acceptance of the assumptions of the conventional science curriculum. Through a review of the literature, I provide a survey of three humanistic pathways in science education: liberal, renewal, and cultural-progressive. I developed activities in cooperation with a high school biology teacher based on these approaches: drawing pictures of science-in-action, a specialized gallery walk, a role play, and the storyboarding of a science-oriented public service announcement.
Utilizing qualitative research methods and drawing on the concept of figured worlds (Holland, Lachicotte, Skinner, & Cain, 1998; Urrieta, 2007), this project was conducted in a high school biology classroom with a diverse range of students. Research methods included classroom observations over a period of eight weeks, ethnographic interviews, artifact collection and analysis, pile sorts, rank ordering, and oral and written reflections by the teacher and her students.

Analysis of this data suggests that the meanings of science for students and their teacher were diverse and emergent through the interactions of personal histories and developing identities, activities, and reflection. This research further illustrates how integrating the plurality of the humanistic approaches to science education provides ways for students and teachers to engage in meaningful, rich, and cognitively challenging experiences. Such experiences allow for the exploration of meaning and possible identities in and with science.
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Lastly, I thank and dedicate this work to my wife Nina. Her perfect combination of encouragement and critique has propelled me through this process, and the sacrifices she has made to allow me to complete this dissertation and the work towards this degree have not gone unnoticed. I feel lucky to have been able to share a life with and be supported by so wonderful a person and a friend.
# Table of Contents

**ABSTRACT** .......................................................................................................................... ii

**ACKNOWLEDGMENTS** ........................................................................................................ iv

**CHAPTER ONE: INTRODUCTION** ......................................................................................... 1

  - Problem Statement .............................................................................................................. 5
  - Research Questions ............................................................................................................. 7
  - Theoretical Foundations .................................................................................................... 7

  - From Science to Classroom: The Emergent World of the Science Classroom ........................................ 8

  - From Classroom to Agent: Meaning and Deliberation in and around the Science Curriculum .................................................. 11

  - From Deliberation to Reflection: The Design of Activities ............................................ 17

**CHAPTER TWO: LITERATURE REVIEW** .............................................................................. 20

  - Assumptions of the Conventional Approach to Science Education ................................ 21
    - Naive Empiricism ............................................................................................................ 22
    - Narrow Instrumentalism ................................................................................................. 24

  - The Two Assumptions and Curricular Change ............................................................ 27
    - The Two Assumptions as a Foil to the Negotiation of Meaning .................................. 30

  - Humanistic Pathways in Science Education .................................................................. 33
    - Liberal Humanistic Pathway ......................................................................................... 39
    - Renewal Humanistic Pathway ....................................................................................... 40
    - Cultural-Progressive Pathway ....................................................................................... 44

  - The Case for Pluralism in Humanistic Science Education ............................................. 50
Meaning, Deliberation, and a Humanistic Approach to Science Education ...... 51

CHAPTER THREE: METHODS ................................................................. 54

Participants .......................................................................................... 54

Time Frame and Units of Study ........................................................... 56

Activity Design ...................................................................................... 57

Gallery Walk ........................................................................................ 62

Drawing Science ................................................................................... 64

Role Play ................................................................................................. 64

Framing Science Public Service Announcement ................................... 65

Data Collection ...................................................................................... 67

Data Analysis and Interpretation ......................................................... 75

Research Quality and Rigor ................................................................... 79

CHAPTER FOUR: MAPPING THE FIELD OF SCIENCE AND EDUCATION .... 81

Gaining Knowledge: Ms. Stoneham’s Perspective on Science ............... 81

The Subject of Science’s Process: Ms. Stoneham and Science Education .... 89

Acting in the Field: Ms. Stoneham’s Roles of the Teacher ....................... 93

Knowing in the Field and the Role of the Teacher: Introducing the Student Perspective ........................................................................ 100

Practice and Learning: Students and Science Education ....................... 106

Students and Science ........................................................................... 110

Drawing Science ................................................................................... 110

Gaining Knowledge .............................................................................. 112

Science as Collection ........................................................................... 113
Science as Activity .......................................................................................... 114
Science as Nature .......................................................................................... 115
Understanding the Relationships between Stories of Science-in-Action .... 119
“Typical” Science .......................................................................................... 121
“Making Things” Science ............................................................................. 123
Science, People, and Communities ............................................................... 124
Teaching Science .......................................................................................... 124
Student Sorts and the Umbrella of Science ................................................. 125
Leah and Identity-Centered Sorting ............................................................... 125

From Field to Meaning .................................................................................. 129

CHAPTER FIVE: EXPLORING THE MEANINGS AROUND SCIENCE AND
SCIENCE EDUCATION .................................................................................. 131

Influence, Value, and Meaning in the Science Classroom ............................. 132
Private Meanings and the Science Classroom ................................................. 142

Ms. Stoneham: Recognizing the Teacher as an Experienced Person ............ 144

Past Experiences .......................................................................................... 144
Coexisting in Relationships .......................................................................... 145
Anticipating the Future ................................................................................ 146
Knowledge and Values ................................................................................ 147

Listening to Students: Experience and Participation .................................... 153

Debra: Memories, Hopes, Fears, and Language ........................................... 154

Past Experiences .......................................................................................... 155
Coexisting in Relationships .......................................................................... 157
Anticipating the Future: Models of Success..............................................157
Anticipating the Future: Status and Fears .............................................161
Leah: Confronting the Brick Wall ............................................................163
Raising the Brick Wall .............................................................................164
Past and Present Experiences and Relationships ..............................165
Anticipating the Future ............................................................................168
Knowledge and Use ................................................................................170
Kimberly: When Science Falls Flat ..........................................................173
Knowledge, Growing Up Stupid, and Success ......................................175
Personal Meanings and Learning and Teaching Science ......................178
Negotiating Meaning through Activity ..................................................179
The Big Idea and the Gallery Walk ..........................................................180
Framing and Introducing the Activity .....................................................180
Social Interactions ....................................................................................181
Artifacts and Reflections .........................................................................182
The Second Gallery Walk: The Emergence of Collective Practice .........186
Social Interactions ....................................................................................186
Artifacts and Reflections .........................................................................187
Playing the Game: The Emergence of Shared Practices .......................191
The Role Play and the Unfolding Complexities and Meanings of Science 193
Introducing and Framing the Activity .....................................................194
Social Interactions ....................................................................................199
Scientific Simplicity: Liking or Disliking Dogs ......................................200
Leveraging Positionality to Promote Seeking and Meaning.............................. 251

Granting Agency to Students as Interpreters ................................................. 252

Choice and the Humanistic Science Curriculum ............................................. 255

The Three C’s and the Recognition of Time .................................................... 257

Conclusion ........................................................................................................ 258

REFERENCES .................................................................................................. 259

APPENDICES ............................................................................................... 280

Appendix A: Teacher Interview Protocol (Stage 1) ........................................... 281
Appendix B: Teacher Interview Protocol (Stage 3) ........................................... 283
Appendix C: Student Interview Protocol (Stage 1) .......................................... 286
Appendix D: Student Interview Protocol (Stage 3) .......................................... 288
Appendix E: Base Protocol for Gallery Walk Activity ........................................ 291
Appendix F: Base Protocol for Drawing Science Activity ................................. 296
Appendix G: Base Protocol for Role Play Activity ........................................... 302
Appendix H: Base Protocol for Framing PSA Storyboard Activity .................... 306
Appendix I: Vignettes of Science-in-Action .................................................... 314
Appendix J: Aggregate Proximity Matrix and Cluster Optimization Analysis for Pile Sort .......................................................................................... 318
Appendix K: Potential Influences on Science .................................................. 319
Appendix L: Images of Storyboards ................................................................. 320
LIST OF FIGURES

Figure 2.1  Humanistic Pathways in Science Education .......................................................... 37
Figure 3.1  Detailed Timeline of Classroom, School, and Research Activities .......................... 59
Figure 3.2  Interview Questions Related to Research Questions ................................................ 76
Figure 4.1  The Claim-Evidence-Reasoning Framework on Ms. Stoneham’s Bulletin Board ................................................................. 85
Figure 4.2  Roles of the Teacher as Described by Ms. Stoneham ................................................. 94
Figure 4.3  Ms. Stoneham’s Wall with Three Levels of Objectives ............................................ 99
Figure 4.4  Representative Drawings in the Gaining Knowledge Category .............................. 114
Figure 4.5  Representative Drawings in the Science as Collection Category ............................. 115
Figure 4.6  Representative Drawings in the Science as Activity Category ............................... 116
Figure 4.7  Representative Drawings in the Science as Nature Category ................................. 116
Figure 4.8  Multidimensional Scaling Analysis Results .............................................................. 123
Figure 4.9  Leah’s Categories of Science by Identities and Activities ...................................... 128
Figure 5.1  Diagram of Debra’s Family Relationships and Locales ........................................... 155
Figure 5.2  Responding to Questions ......................................................................................... 182
Figure 5.3  Using DNA and RNA to Recreate Extinct Animals ................................................ 184
Figure 5.4  A Poster Representing Content .............................................................................. 185
Figure 5.5  Posters from the Second Enactment of the Gallery Walk Activity ........................... 187
Figure 5.6  Distribution of Frames Reportedly Employed by Individual Students ......................... 217
Figure 5.7  Representative Drawings of Themes in the Second Activity Carried Over from the First .......................................................... 223
Figure 5.8  Kimberly’s Drawings of Science in Action ............................................................... 224
Figure 5.9  Debra’s Drawings of Science in Action

Figure 5.10  Rosa’s and Juana’s Drawings of Scientists Helping and Improving Communities and the World
LIST OF TABLES

Table 2.1 The Humanistic Pathways in Science Education ........................................ 37
Table 3.1 Activity Structures .................................................................................... 61
Table 3.2 Klafki’s Questions for a Didaktik Analysis .............................................. 63
Table 3.3 Sources and Methods of Collecting Data ............................................... 68
Table 3.4 Criteria and Strategies for Research Quality and Rigor .......................... 79
Table 5.1 Student Rankings of Influences on Their Engagement in Science Class ........................................................................................................ 133
Table 5.2 Ms. Stoneham’s Influences Rankings .................................................... 148
Table 5.3 Sample Student Reflections on the Role Play ....................................... 214
Table 5.4 Student Storyboards and Quotations from Reflections ........................ 219
CHAPTER ONE: INTRODUCTION

Understanding science has become an increasingly important aspect of civic participation and economic opportunity in contemporary society. As such, the purposes and value for teaching and learning science is entangled with multiple layers of meaning. Science education in schools, however, is often designed based on the assumption that the meanings around learning science are implicit within the facts of science themselves (Donnelly, 2002) and is frequently inconsistent with students’ lived experiences (Aikenhead, 1996, 2001; Brickhouse & Potter, 2001; Costa, 1995). Science is therefore seen by students as an endeavor for someone else, contributing to a lack of access to the knowledge necessary to address the scientific and environmental issues faced by them and their communities (Calabrese Barton, 2002; Fraser-Abder et al., 2006).

What I refer to as the “conventional science curriculum,” or what one often sees when handed a typical science textbook, often takes its cues from what Holton (1991 in Girod, 2001) refers to as “public science”—or better yet, the public face of science. This public face of science is concerned primarily with an objective and factual approach while ignoring or discounting the “messy, disordered, exciting science” (Holton, 1991 in Girod, 2001, p. 20). By relying on the public, objective, and factual face of science, questions of ends, meanings, and values are also effectively discounted or ignored. Indeed, if one agrees with Gould (2003), these questions lie outside the realm of science, and based on its methods, modes,
and approaches of inquiry, Gould argues, such questions should not be handed to
science for good reason. It can be easily argued, however (and has been: e.g.,
Scheffler, 1992), that such examinations are a necessary function in science
education, if not in the practice of science.

The conventional science curriculum, conveying what and how science
educators should teach, rests upon a combination of three default purposes: 1) Presenting students with the facts of nature that can be understood only if seen in
the right (scientific) way (Milne, 1998); 2) Assuming the induction of students into
scientific professions as the primary and end goal (Aikenhead, 2005; Olitsky,
2006); and 3) Assimilating students into an idealized scientific worldview (Carey,
1986; Stanley & Brickhouse, 1994). These default purposes are embodied in the
content, pedagogies, and activities of the conventional science curriculum
(Roberts & Östman, 1998). These purposes often do not take into account the lives
and worlds of students, nor do these purposes take seriously opportunities for
students and teachers alike to engage deliberatively and reflectively in the learning
and teach of science, reinforcing a sense of alienation from science.

It should be noted that I am not discounting these goals as neither
important nor necessary. Instead, I am making the assertion that the uncritical
acceptance of the assumptions, practices, and outcomes that these tacit goals
engender run the risk of alienating students from science and disengagement from
the discourse around science. Students’ disengagement from science can be seen
in contemporary society in several ways. One way this can be seen is the proportionally low enrollment in science at the college level and in scientific careers with the exception of those who exhibit an apparent aptitude for science (Preston, 2004). This is an extension of the findings of Aikenhead (1996), who demonstrated that students who can be categorized as “Potential Scientists” or “Other Smart Kids” tend to excel in school science, while other students do not.

Another way is the declining status of established scientific understandings in the public discourse (Mooney & Kirshenbaum, 2009). Science and technology are framed in particular ways that can be inconsistent with the consensus of the scientific community (Nisbet & Scheufele, 2009) or placed in a “black box” (Latour, 1999) and treated as something magical, terrifying, or inevitable. The discourse around human-influenced climate change, the status of evolution in the school curriculum, and contemporary society’s reliance on digital technology can all be viewed in this light. We increasingly find that “[w]e’ve arranged a global civilization in which most crucial elements... profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology” (Sagan, 1995, p. 26). Education in the United States has long been seen as an integral factor of a healthy democracy (Dewey, 1961; Kliebard, 2004); as understanding science becomes more important in contemporary society, finding ways to open up the “black box” in the science curriculum becomes more important.
A broad body of empirical and conceptual research highlights the importance of transcending the default purposes conveyed through the conventional science curriculum and working to connect science learning to lived experience (e.g., Aikenhead, 2005; Calabrese Barton, 2002; Hurd, 2002). One way to foster this connection is to provide students the time, place, and structure to deliberatively and reflectively negotiate meaning around the science curriculum. This negotiation of meanings allows students to find their place in science—as well as the role that science fills for them and their communities. By providing students a voice through the negotiation of meaning we can move from conceiving the science curriculum as a static body of facts to a “lived curriculum” (Hurd, 2002), in which learning provides connections with the lifeworld of the student.

I am seeking to empirically understand through research the limits and possibilities of the explicit negotiation of meaning around the science curriculum. Building upon my research, I also aim to provide the curriculum development field with not only a better understanding of how students and teachers negotiate meaning in the classroom, but also recommendations for activities and activity settings—the time, place, and structure—to support this process. This research is also undertaken to authorize students’ perspectives and grant students voice in science education reform efforts. This allows educators—teachers, curriculum developers, researchers, and policy makers—to hear students and the meanings they negotiate around their science learning. Hearing and engaging students are
important as each new generation continues to face the scientific and environmental challenges we only begin to experience (Calabrese Barton, 2002; Hodson, 2003; Hurd, 1997).

**Problem Statement**

In this dissertation, I conduct a qualitative study using ethnographic methods in which I seek to investigate approaches to providing structures and activities for students and teachers to negotiate meaning around the science curriculum and to connect with lived experience. Although a fuller discussion of the negotiation of meaning will be provided later, at a basic level, “…the negotiation of meaning refers to the ongoing process of making sense out of our experience in a social world that we at once inherit and create” (Levinson & Brantmeier, 2006, p. 330). It is also necessary to consider that meaning is negotiated within a field, a set of other meanings, experiences, and structures which provide context and relationships for meaning (Taylor, 1990). In exploring how this negotiation occurs in the field, I conducted research in a high school science class for two months during the 2010-2011 academic year.

Over the course of this research, I seek to address three interrelated problems: one empirically-oriented, one change-oriented, and one design-oriented. Few studies frame the science curriculum as an opportunity to facilitate the negotiation of meaning between students and teachers. As such, to address
In a historical survey of science curriculum reform efforts, Hurd (1997, 2002) has found a repetitive cycle of small modifications to the conventional approach to science education. If we conceptualize curriculum as one platform for educational change, providing students the opportunities to negotiate meaning within the contexts of their communities, experiences, and backgrounds is one way to begin to transcend the repetitive cycle of reform. We must also listen to and act upon what they say. As such, it is necessary to respond actively to the call and challenge presented by Hargreaves and Shirley (2009) to position students as partners in—rather than targets of—educational change. Therefore, by addressing this change-oriented problem, I plan to work with the classroom teacher to craft activities which provide the structure, time, and space for students to become reflective partners in the negotiation of meaning around the curriculum, treating these activities as opportunities for authorizing students’ perspectives (Cook-Sather, 2002).

Lastly, there is a lack of general guidelines and principles for developing curriculum-based activities to grant students the opportunities to sort through and contribute to the meanings of their own learning in science as they live in their communities and prepare for their futures and the people they are becoming with science education as an important contributor to this process. To address this
design-oriented problem, I explored these practices and provide insights and guidance to the field around the design of future curricula and educational materials.

Research Questions

In orienting my research, I ask the overarching question: What are the relationships between meaning and science that surround the science curriculum for a teacher and her students? To further this inquiry, I ask three sub-questions:

- How do a teacher and her students describe the field in which the negotiation of meaning takes place?
- What are the meanings that arise when a teacher and her students are provided the structures and activities to explicitly negotiate meanings around the science curriculum?
- How can teachers and curriculum developers use these processes of meaning negotiation to understand students in terms of where they are, where they have been, and how to guide them in the future?

Theoretical Foundations

The theoretical framework for this research draws primarily upon the concept of figured worlds (Holland et al., 1998; Urrieta, 2007) to illuminate the negotiation of meanings around the science curriculum. The figured worlds framework provides a robust vocabulary and structure for exploring meaning and identity in a social setting such as a classroom. In detailing the theoretical and
philosophical foundations for this research, I first provide a brief overview of my reading of the figured worlds framework. Second, I provide a review of an approach to meaning and the negotiation of meaning in the science classroom. Lastly, I provide a brief theoretical grounding for the design of the activities utilized in this research.

**From Science to Classroom: The Emergent World of the Science Classroom.** To ground this investigation, I draw upon the concept of figured worlds (Holland et al., 1998) to inform my approach, recognizing the close relationships between meaning, identity, and the power of the curriculum to evoke unique modes of participation in an evolving world continuously on the make (Urrieta, 2007). Holland et al. (1998) define the concept of figured worlds at its most basic level as “...a socially and culturally constructed realm of interpretation...” (Holland et al., 1998, p. 52). Suspended and supported by cultural and personal “webs of meaning” (Geertz, 1973), figured worlds are, in a sense, a space for identity development within a culturally and individually significant realm. In the context of this figured world, identities play out (or, in other words, are “figured”), significance is granted to particular discourses and practices, and particular outcomes are valued over others (Holland et al., 1998). It is this intersection of identities, practice, and significance within the figured world of the classroom which forms the foundation of this study.
Towards this mode of analysis, the concepts of “positionality” and “space of authoring” stemming from the figured world framework are useful ideas in science education research. In considering the power structures in the science classroom—affected a great deal by external factors such as school structures, societal expectations, and parental and peer influences—positionality refers to the “positions” available to students and teachers and the roles they are afforded (Urrieta, 2007). Positionality is dependent upon the relations and contexts in which actors find themselves. Holland et al. (1998) describe spaces of authoring as a crafted response to the world at hand by “…arranging the identifiable social discourses/practices that are one’s resources” (Holland et al., 1998, p. 272). In more authoritarian situations, the response may be more automatic; agency, on the other hand, relies on “improvisation” and borrowing from practices across one’s full range of personal history and community backgrounds. Also influenced by power dynamics, the spaces of authoring are those afforded to actors to respond to and create worlds of their own design, based on the range of experiences and practices at their disposal. Providing appropriate spaces of authoring in the classroom allows students and educators to reach across the range of experiences and backgrounds to bridge their home cultures and communities with science.

Drawing on Vygotsky, Holland et al. point to the importance of pivots, which serve as mediating devices to organize responses as well as to help actors “...pivot or shift into the frame of a different world” (Holland et al., 1998, p. 50). By
this definition, the science curriculum is a material artifact, along with other material and symbolic artifacts, which can serve as a pivot to “evoke” a figured world (Urrieta, 2007, p. 110). The ways in which the science curriculum evokes a world, and the spaces of authoring the science curriculum allows is the focus of this research.

It must also be remembered that, from a cultural perspective, the science classroom is also a site where a number of different communities intersect through the interaction of its members (Seiler & Elmesky, 2007). Students and teachers—as human agents with diverse cultural, linguistic, racial, class, and experiential backgrounds—are members of multiple communities. Individuals are examples of “history in person” (Holland & Lave, 2001): these historical factors are not “checked at the door” when entering the classroom, but have a bearing on the practice in the classroom, bringing a diversity of meanings to the experiences of the classroom and curriculum. This influx of meanings around the science curriculum and classroom is further influenced by a range of structural factors, such as policies, politics, and notions of national and global competitiveness (Fensham, 2009; Fraser-Abder et al., 2006).

Educational research must account at some point for the growth and development of the individual learner (Erickson, 1982) and to take seriously what Turner (1974), drawing on the work of sociologist Florian Znaniecki, refers to as the “humanistic coefficient.” Turner writes, “...sociocultural systems [such as
figured worlds] depend not only on their meaning but also for their existence upon the participation of conscious human agents...” (V. Turner, 1974, p. 17; emphasis in the original). As such, the exploration of meaning is a keystone for identity development and a way to understand the deliberative nature of figured worlds in the science classroom.

**From Classroom to Agent: Meaning and Deliberation in and around the Science Curriculum.** The students and teachers—the conscious human agents—who construct and inhabit the figured world of the science classroom negotiate meanings on an ongoing basis (Wenger, 1999). Such negotiation frequently occurs tacitly and favors the default purposes and meanings embodied in the curriculum (Aikenhead, 2001). This tacit form of negotiation favors students who already know how to succeed in science at the expense of finding ways for students to become scientifically knowledgeable members of their communities or to provide access to science for students who may be interested in science-based professions but do not know where to begin (Aikenhead, 1996, 2001; Brickhouse & Potter, 2001).

However, I also consider the idea that students, teachers, and curriculum developers have the potential to be active participants in the emergence of figured worlds in the classroom. Providing opportunities for teachers and students to focus on meaning is a way towards a more inclusive science education experience. In this section, I provide a survey of an approach to the exploration of the
negotiation of meaning. It should be noted that what follows is not an account of the actual negotiation of meaning, but a particular approach to understanding its processes and products. What follows is a map, not the territory.

In locating a description of meaning, Taylor (1990) describes the three-dimensional structure of experiential meaning (of a situation, event, or experience). First, meaning is for a subject or agent or a group of subjects, such as a community. Second, meaning is of something, so that meaning is distinguishable—although not necessarily separable—from the situation, event, or experience. Third, something can only have meaning in a field, so that meaning only stands in relation to other meanings, experiences, and structures.

Taylor provides a useful and robust framework for the structure of meaning. Similarly, Frankl (1966) provides an excellent overview of the principle pathways by which meaning unfolds:

…first, by what he gives to the world in terms of his creation; second, by what he takes from the world in terms of encounters and experiences; and third, by the stand he takes when faced with a fate which he cannot change. (emphasis added; Frankl, 1966, p. 23)

According to Frankl, meaning emerges when a person engages in a creative act, such as crafting or making something. Within the context of the classroom, this could take on many forms, such as a poster, a presentation, a paper, or a project. In the act of this creation, the person provides meaning to the world. Frankl also described meaning as emerging when a person encounters or experiences another

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1 The gendered language in this passage is maintained in deference to the original text.
person, an idea, or activity. Again, in the context of the classroom, this may be an inquiry activity, a special relationship with a peer or teacher, or simply learning something new or surprising. In this case, the person is able to find meaning in this experience. Lastly, Frankl described meaning as emerging when a person is forced to take a stand in the face of uncertain conditions and outcomes. This pathway is perhaps the most overlooked—and the most difficult to incorporate—mode of meaning in the classroom. Much of school in general, and school science in particular, is predicated on certain outcomes: a right or wrong answer, a graded evaluation, a clear delineation between school and the outside world. Yet as science specifically has come to play a much larger role in society’s functioning and meaning, as well as holding the keys to the causes, processes, and potential solutions to environmental degradation, students of science need to learn to take stands on these issues. While school need not necessarily be indistinguishable from the society at large, it can serve as a site to prepare and practice for these stands, such as through role plays and other identity- and role-focused activities.

There are other ways in which meaning provides insight into the deliberative and identity-focused nature of figured worlds. For example, meaning provides a sense of coherence. In an individual sense, coherence provides the learner the ability to incorporate new understandings into the larger narrative of their life (Bruner, 1990, 1996) and expands his or her “horizon” of understanding by thinking and talking about the object with greater complexity and specificity.
(Eger, 1992; Gadamer, 2004). Socially, through coherence in meaning, an emergent common language (Agassi, 1994) is negotiated, informed by the practices, structures, and community expectations found in that time and place. Yet coherence through meaning also bridges time and place, as Turner writes, “Meaning arises when we try to put what culture and language have crystallized from the past together with what we feel, wish, and think about our present point in life” (V. Turner, 1986, p. 33).

Furthermore, currency emerges along with meaning, granting the experience a relative degree of importance or significance (Wenger, 1999). Currency also enables for the further negotiation of meanings at other times and places and in different communities, such as negotiating meanings of ideas from the community of scientists in classrooms and in the students’ home communities.

The idea of currency cannot be discussed without exploring the notion of values. Corrigan and Gunstone (2007), in introducing the concept of value-guided science education, drew on the work of Halstead (1996, p. 5, in Corrigan & Gunstone, 2007) to define values as:

The principles, fundamentals, convictions, ideals, standards, or life stances which act as general guides or as points of reference in decision-making or the evaluation of beliefs or actions which are closely connected to personal integrity and personal identity.

Values then emerge at the nexus of meaning, ideals, and identity, and encompass the idea of currency described above. Much as coherence provides a bridge to a
remembered past, values provide a pathway forward to a desired future. Frankl (1966) outlined a tripartite description of values in parallel to his three pathways of meaning: creative, experiential, and attitudinal values. How people act according to these values have profound and lasting impacts on the shaping of figured worlds, in addition to the roles that they play.

In congruence with the figured world notions of positionality and authorship, as well as with the ideas of currency and values posited above, meaning has the potential to engender agency and action. Following Ahern (2001), I position agency at its most basic level as “...the socioculturally mediated capacity to act” (Ahern, 2001, p. 112) which is forged (c.f., Keane, 2003) among knowledgeable human agents (Giddens, 1986). Agency also provides a normative and evaluative aspect, providing the means for individuals to judge the outcomes of their actions (Emirbayer & Mische, 1998). In my conception, this agency forged through the negotiation of meaning serves as the keystone between meaning and identity. As Wenger (1999) notes, “What makes information knowledge—what makes it empowering—is the way in which it can be integrated within an identity of participation...” (Wenger, 1999, p. 220). Some ways in which this integration occurs is through telling stories, engaging in dialogue, renewing understandings, or participating in directed action. This approach to meaning provides students—and teachers—with a way to draw upon and in a sense reframe, utilize, and
embody scientific understandings for many purposes, moving beyond the default purposes of science education and shaping the figured world of the classroom.

When positioned against coherence, currency, and values, agency requires a degree of reflexivity and deliberation on the part of the actor. Indeed, according to Archer (2000), it is this capacity to reflect and deliberate on our practices and intents that make us human and provides us the opportunity to shape our world as it emerges. This focus on deliberation and reflection is consistent with taking the “humanistic coefficient” seriously and a necessary assumption in the exploration of meanings around the science curriculum. I will present one caveat regarding this perspective and approach in the Literature Review of this dissertation.

Approaches to science education focusing on meaning often cause discomfort and are discounted in the contemporary American school environment (Carson, 2004). Science is often assumed to be instrumental, in that it carries its own set of non-negotiable and empirically-validated meanings (Donnelly, 2002). Many science textbooks and curricula are modeled after the quest for replicability and objectivity inherent in the natural sciences and are organized around discrete scientific concepts (Milne, 1998). Given this reality, I will discuss the development of activities within appropriate settings and structures with the goal of reflective negotiation of meaning around the science curriculum next.

From Agent to Doing and Reflecting: The Design of Activities.

Wenger (1999) asserts that “[l]earning cannot be designed: it can only be designed
for” (emphasis in original; Wenger, 1999, p. 229). My purpose in designing activities is not to elicit from students a particular quantifiable outcome or formula for efficiency, but rather to foster a process of negotiating meaning around the science curriculum by teachers and students where the outcome is not necessarily known. It is also important to consider the activity settings (MacDonald & Shirley, 2009) such as time, place, and the value (or currency) which the activity is granted.

As potential pivots and spaces of authoring, with a focus on meaning and activity settings, learners and teachers are provided the opportunity to explore such questions as, “What is the place of learning science as I live my life? What is my place in the larger narrative of scientific discoveries and scientific communities? What is the role of science in what I expect of myself and what my communities expect of me?” These questions guide the design process and provide a set of generative topics (Stone Wiske, 1998) for teachers and students, nurturing opportunities for negotiation and reflection.

In order to frame the overall design, I draw upon the framework of Levinson and Brantmeier (2006), who outline four approaches to the design of activities in order to foster deliberative practice in the classroom:

- **connective** practices which promote greater participation in and out of the classroom;
- **simulative** practices which provide opportunities for developing skills and dispositions;
• *cooperative* practices in which respect between students and teachers is fostered;

• *exemplary* practices which provide opportunities for learning from mentors and models.

With my research and practical goals in mind, I add *reflective* to this list. Reflective practices provide opportunities to consider and discuss experiences in the classroom. While activities by themselves cannot cure the woes of the educational system, this focus on the design of activity structures is one important approach (Levinson & Brantmeier, 2006) when considered within the larger contexts of education in general and science education specifically.

In general, deliberation and meaning are important and necessary components of the educational process in science education in order for teachers and students to fully grasp the ways in which lived experiences impact the learning of science, and how science impacts and influences participation in a broader society and specific communities. The conventional curriculum does not allow for the full range of deliberation and meaning, and therefore I seek to find ways to transcend the conventional science curriculum by addressing these problems from empirical, design-oriented, and change-oriented perspectives.

Having defined the boundaries of the problem, set up the research questions, and laid out the theoretical framework of this research regarding the negotiation of meaning around the science curriculum, several points still need to
be more clearly expressed. In the next chapter, the Literature Review, I will outline the assumptions which underlie the “conventional” science curriculum. I will then refer to an alternative approach, the humanistic approach to science curriculum and research as an alternative to the conventional science curriculum, and in a survey of the literature, describe the humanistic approach’s three Pathways.
CHAPTER TWO: LITERATURE REVIEW

As indicated earlier, an approach which foregrounds meaning and opens this concept to negotiation within the context of science education requires that we transcend the conventional science curriculum in order to provide the time and place for this negotiation. I had alluded earlier that the conventional science curriculum is the default curriculum, the curriculum which is enacted without critical thought, deliberation, reflection, and negotiation of meaning by educators, students, and even curriculum developers themselves. In this review of the literature, I will describe two underlying assumptions of the conventional science curriculum: naïve empiricism and narrow instrumentalism. Secondly, I will provide a survey of three Humanistic Pathways in science education which provide a strong foundation for working around the conventional science curriculum and form a solid base for the negotiation of meaning between students and teachers. The three Pathways I describe are Liberal, Renewal, and Cultural-Progressive Humanism, each with examples from the literature. Lastly, as both frameworks playing important roles in this research, I will consider the ways in which the figured worlds approach to research and the Humanistic Pathways in science education interact in terms of areas of congruence and discord. In doing so, I will provide an avenue for the use of the figured worlds framework in empirical research in light of the humanistic pathways through science education and curriculum.
Assumptions of the Conventional Approach to Science Education

Educational curriculum in its ideal sense, according to the thinker Martin Buber, would represent “...a selection of the world... lifted out of the purposelessly streaming education by all things, and is marked off as purpose” by the educator (Buber, 1965, p. 89). This description is deceivingly complex. Curriculum, according to Buber, arises from the flow of living in the world, but marked off as purposeful by the educator (teacher, curriculum developer, etc.). This dialectal dance between the streaming of all things and educational purpose requires judgment and thoughtfulness on the part of the educator, in which she is mindful of both the requirements of society in terms of what constitutes a scientifically-educated individual and the needs and preferences of students in the class.

In the introduction to this research, I outlined three purposes that by convention are hallmarks of the science curriculum: 1) Presenting students with the facts of nature that can be understood if seen in the right (scientific) way (Milne, 1998); 2) Inducting students into scientific professions (Aikenhead, 2005; Olitsky, 2006); and 3) Assimilating students into an idealized scientific worldview (Carey, 1986; Stanley & Brickhouse, 1994). As stated earlier, these purposes do not necessarily account for the lived experiences of and assigned meanings by students and teachers. Drawing upon Buber’s definition of curriculum, these three purposes divert rather than mark the stream of life, denying the time and place for
the negotiation of meanings that social actors bring to the educative process and forcing figured worlds into particular—rather than emergent—shapes.

In this first section of the review of the literature, I will demonstrate that these three purposes further rely upon and are held in place by two key assumptions: naïve empiricism and narrow instrumentalism. In a sense, these assumptions are reflections of the times in which we find ourselves, educational manifestations of the broader contemporary zeitgeist, but are particular to the teaching of science and the design of science curriculum. When viewed through a broader lens, I will demonstrate how these assumptions are bolstered by a broader educational change framework divergent from its promises, namely the “Three Paths of Distraction”—autocracy, technocracy, and effervescence—as described by Hargreaves and Shirley (2009). I will also demonstrate how the manifestations of these assumptions serve as a foil to the negotiation of meaning around the science curriculum.

**Naïve Empiricism.** The enterprise of science is framed in multiple ways through stories for the purposes of teaching and learning. The assumption of naïve empiricism is particularly in line with two types of science stories as described by Milne (1998): declarative and discovery. “Declarative science stories” are those representations of science in which scientific concepts and processes are set as “secure and timeless” objects, which can be seen by anyone as long as the correct (scientific) lens is applied to the observation of nature (Milne, 1998, p. 175).
“Discovery science stories” present the growth of scientific knowledge as accidental, such as the familiar—yet inaccurate—legend of Christopher Columbus (re-)discovering that the Earth is round (Eco, 1998) or the account that the structure of the six-carbon benzene molecule came to the German chemist August Kekulé in a vivid daydream of slithering snakes (Robinson, 2010). In such curricular and pedagogical representations of science, “...naïve empiricism neglects the interpretive and contestable nature of science” (Brickhouse, Stanley, & Whitson, 1993, p. 367).

Requiring students to memorize scientific facts and events is frequently the educational symptom of a naïve empiricist account of science (Driver, Newton, & Osborne, 2000). Other pedagogical approaches beyond rote memorization—even open-ended and socially-oriented approaches such as the inquiry approach—can succumb to naïve empiricism. Donnelley (2004), for example, describes the situation in which the open and potentially creative approach of inquiry can be at odds with the scientific canon as students struggle to replicate the “preferred explanations” of accepted science without the appropriate tools, contexts, and full depth of background knowledge and scientific history that originally preceded the canonization of the scientific concepts under study. This dissonance can lead to frustration and a feeling that science is beyond students’ grasps because they just can’t see nature—or make science happen—in the correct or “ready-made” way (c.f., Latour, 1999).
As such, a naïve empirical approach to science discounts the contingent and historical nature of scientific understanding (Gould, 2003). Rather than considering science as the aggregation of understanding gained by exploring and explaining the universe through a particular—scientific and methodical—approach, a naïve empirical approach considers science as a static collection of objective facts or a sporadic series of accidental discoveries. Kekulé’s daydream-as-discovery perspective under this assumption are simply the product of luck rather than the story of a hard-working scientist building on the foundations of existing scientific theory and human knowledge. Nor does this perspective acknowledge the highly visual nature of science in general and chemistry in particular (Robinson, 2010). Naïve empiricism fuels the presentation of the facts of nature in the practice of science education, while providing impetus for taking on assimilation and induction into the scientific enterprise as the tasks of science education. Naïve empiricism does not stand alone in science education, as it is closely tied to a second assumption, a narrow sense of instrumentalism.

**Narrow Instrumentalism.** The second assumption which underlies the three default purposes of science education is narrow instrumentalism. This assumption stands apart from the deeper sense of instrumentalism associated with Deweyan pragmatics, which is aimed at improving the human condition from an ethical and progressive position and allows the individual to exercise moral
judgment (Rudolph, 2005). According to Donnelley (2002), instrumentalism is an ontological feature of the natural sciences exhibiting a three-fold structure:

1. *Elimination of the personal*, in that the scientific enterprise eschews the fuzzy human characteristics of judgment, purpose, personality, motivations and broad experience. Instead, scientists take the mythical “god’s eye view” of the universe, removed from the objects of study in order to maintain objectivity.

2. *Demarcation from ethics*, in which science can be useful in describing the world, and even how the material world can be manipulated, but science is not able to provide the moral and empathetic imagination and categories of judgment for how the world *ought* to be. In a sense, science becomes “value-neutral” and interventions in the natural world are reduced to pure mechanics.

3. *Absence of reflexivity*, a point contingent upon the previous two, which indicates that the scientific enterprise is solely focused on the material world so that while *scientific knowledge* may accrue, *scientists themselves* do not necessarily grow and develop as self-aware and self-understanding human beings through the practice of science.

In following this argument, it is first necessary to understand that Donnelley’s assertions are extreme positions of three continua rather than
statements of fact about practitioners of science. His assertions are made in order to provide a strong contrast against which to provide an alternative in science education. Secondly, we must make the distinction between “science” and “science education” (Sherman, 2004). This form of instrumentalism to some degree is not only appropriate but valued in the practice of science; it does not, however, necessarily lead to best practices in science education. Scheffler (1992), for example, asserts that while the scientist need only do science by embodying the mental habits of the scientific enterprise, the science educator

...is concerned with the deliberate processes through which forms of thought may be handed on; he strives not only to understand these [scientific] processes but to institute or facilitate them.... To make his own objectives intelligible, the educator needs to be able to analyze and describe those habits which it is his purpose to hand on to the next generation. (Scheffler, 1992, p. 390)

According to Scheffler, as much as science is instrumental in this narrow sense, science education is not. Education relies on the personal, ethics, and reflexivity for its proper activity. Yet in the field of science education narrow instrumentalism can be found in abundance, and perhaps best expressed as a reliance on the dictum of Sir Francis Bacon, “Nam et ipsa scientia potestas est” (knowledge, itself, is power; Bacon, 1857-70, p. 241 in Donnelly, 2002, p. 141) Placing the personal, the ethical, and the reflexive in absentia, and positioning science knowledge itself as power in science education, allows for an opening for a reliance on efficiency and on the “bottom line.” Linked closely with naïve empiricism,
science becomes a “black box” (Latour, 1999), a shallow and factual representation of the depth of understanding and discourse that accompanies each and every scientific concept.

It must be understood that instrumentalism is an important and prominent aspect of science, and it is important to teach about this idea in science education. Reliance on an instrumental perspective has reaped important gains in knowledge, understanding, and activity in both the scientific enterprise and in schools. Even Martin Buber, a great critic of the instrumental perspective, recognized the importance and benefits of instrumentalism: “And in all seriousness of truth, listen: without It a human being cannot live. But whoever lives only with that is not human” (It in Martin Buber’s terminology is an instrumental approach to relating to others and the world; Buber, 1996, p. 85). A life cannot be lived without adopting an instrumental approach at times, yet it is the “anti-instrumental”—the personal, the ethical, and the reflexive—which make us human. Buber’s statement is echoed by Brickhouse et al. (1993), in their claim that, “...we need to understand that it is not possible for humans to have a purely instrumental or technical competence” (Brickhouse et al., 1993, p. 364). It is important not to uncritically and tacitly accept the narrow instrumental default assumptions of science education as a way of being, and translate it into the purposes of science education.

The Two Assumptions and Curricular Change. When we only focus on science education through a narrow instrumental lens and adopt a position of
naïve empiricism, we run the risk of narrowing the science education opportunities of children. Weinstein (2008) refers to this broad educational reliance on narrow instrumentalism and naïve empiricism as the “technosociality” of schools:

...from the multiple ways students are sorted and selected, labeled, and tracked to the new microtechnologies that monitor academic progress, to the managerial sciences that structure the day, and to the architecture, which envelops schooling, schools are woven pastiches of linguistic, material, cognitive, managerial, accounting, environmental, and metrological sciences.... The science is right here with, in, and around our students; when they enroll in schools they are also being enrolled in a wide variety of scientific projects. (Weinstein, 2008, p. 396)

Bundled together, naïve empiricism and narrow instrumentalism tightly align with the technosociality as described by Weinstein. In essence, Weinstein’s technosociality is the application of the two assumptions of science education to the broader school setting. Narrow instrumentalism and naïve empiricism are mirrored in the broader school structure, data is accepted without considering its meaning. This provides little impetus to seek out alternatives to the conventional science curriculum.

Delving into further detail, there are also connections between the two assumptions and the “Three Paths of Distraction” as outlined by Hargraeves and Shirley (2009). The Paths of Distraction, according to the authors, serve to distract a particular era of school change initiatives—The Third Way—from its intended
tasks of bringing together the best of a government-driven sense of idealism with the practicalities of a market-based approach in education. The three Paths are:

- **The Path of Autocracy**, which calls for tough, surface-level market-driven and economically-influence changes in education without a thorough examination of the assumptions which underlie these changes—the idealization and idolization of the market—and of the human costs.

- **The Path of Technocracy**, which reduces a quest for equity and responsibility “…into technical calculations of student progress targets and achievement gaps…” (Hargreaves & Shirley, 2009, p. 29). This path places all of its faith into numerical test data without thought of what the numbers represent or mean.

- **The Path of Effervescence**, which forces a high degree of interaction between teachers in order to make following the other two Paths “fun.” The emphasis in this Path is providing teachers with an “evanescent ‘high’” (Hargreaves & Shirley, 2009, p. 41) rather than providing a pathway for a quest towards qualitatively and philosophically “good” education.

The followers of these Paths represent a “New Orthodoxy” (Hargreaves & Shirley, 2009, p. 23). The Paths of Distraction exist in a symbiotic relationship with the assumptions naïve empiricism and narrow instrumentalism in science
education. While the two assumptions are curricular in nature and the Paths of Distraction are broader to the field of educational change, aspects of these Paths can be found reflected in the two assumptions. They reinforce each other, buttressing the status quo in educational practice and policy, and preventing alternate pathways from being explored. Hurd (1997, 2002) found a repetitive cycle of small modifications to a conventional approach to science learning and teaching in a historical survey of science education change efforts. In the current round, it is the two assumptions and the Paths of Distraction that are holding science education in place. As such, science education stuck where it is, little room is left for the negotiation of meaning around the science curriculum. When seen reflected in the broader educational structures, these two assumptions of naïve empiricism and narrow instrumentalism are particularly difficult obstacles to overcome in order to seek out alternatives to the conventional science curriculum.

**The Two Assumptions as a Foil to Meaning.** As outlined above, the two assumptions of naïve empiricism and narrow instrumentalism are strongly reflected by the contemporary school structures and are therefore prime shapers of the figured world of the science classroom. Students, and even teachers, are granted little positionality in the face of such structures, and their spaces of authoring are limited. Given the strong undercurrent of these two assumptions, there is little impetus for educators to seek out alternatives to the conventional science curriculum. Three problems, however, arise when seeking to support the
negotiation of meaning within the conventional science curriculum when constrained by the assumptions of naïve empiricism and narrow instrumentalism: what it means to be “knowledgeable,” the bundling of companion meanings, and the lack of currency around the science curriculum.

In reference to what it means to be “knowledgeable,” thinking is considerably limited under the assumptions of naïve empiricism and narrow instrumentalism. With a focus on easily measured and quantifiable data, “knowing something” is exhibited by recalling facts and events to perform to standards on large-scale exams.

In regards to the concept of companion meanings, it is important to be mindful of the fact that the attachment of meanings to experience is a predictable human activity. With the narrowing imbued by the two assumptions, meanings are often bundled with the content in the science curriculum in the form of “companion meanings” (Östman, 1998). Educators and students are expected to accept these companion meanings at face value and even replace their own meanings of the learning experience with these bundled meanings.

With this narrowing and these expectations, other forms of currency for the learning of science—such as educating for citizenship, educating for the development of the whole human being, investigating for personal interest, and educating for political action—are greatly discounted and even ignored (Calabrese Barton, 2002; Fensham, 2009; Hodson, 2003; Lemke, 2001; Wong, 2001). This does
not take into account the cultural and linguistic divides between the expectations of science education and home cultures which can occur in the contemporary pluralistic society (Aikenhead, 2001; Costa, 1995; O. Lee, 2001).

As such, little currency is given to meaning in science education. Its devaluation results in little time and space afforded to deliberative and identity-connected approaches to science education broadly, and acceptance of the default purposes of science education are assumed in the conventional curriculum. This leaves out the voice of both classroom educators and, especially, students, and assumptions go unexamined. With this lack of currency in mind, addressing the empirically-oriented problem and the change-oriented problems outlined in the Introduction are essential for the development of a research agenda. By empirically framing the science curriculum as an opportunity to facilitate the negotiation of meaning between students and teachers and, from a change-oriented approach of crafting activities which provide the structure, time, and space in order to authorize students’ perspectives, research can provide a pathway to transcend the conventional science curriculum and find ways to make the science education process more meaningful. As such, in the next section, I assert that the Humanistic Pathways in Science Education are important alternatives to the conventional science curriculum by affording these opportunities.
Humanistic Pathways in Science Education

In this section, I propose that a “Humanistic” approach to science education is one way to allow for the time and place to negotiate meaning around the science curriculum in the classroom. While I acknowledge that pedagogical, curricular, and research approaches need to be matched with broader changes in policy and societal expectations, approaches such as those mapped in this review provide a model for considering these larger changes.

In defining what a humanistic approach to science education would mean, I look to the political theorist Hannah Arendt and her essay “The Crisis of Education:”

Education is the point at which we decide whether we love the world enough to assume responsibility for it, and by the same token to save it from the ruin which—except for the coming of the new and young—would be inevitable. And education, too, is where we decide whether we love our children enough not to expel them from our world and leave them to their own devices, nor to strike from their hands their chance of undertaking something new, something unforeseen by us, but prepare them for the task of renewing the common world. (Arendt, 1993, p. 196)

In utilizing this passage as a starting point for a humanistic approach to science education, I first need to explain several terms that Arendt uses in specific senses. Writing at a time when the specter of nuclear war was very real and the Holocaust of World War II was still fresh in the public imagination, the “world” for Arendt represents the set of human accomplishments that are durable over time: great works and the accumulation of human understanding and knowledge
important for the continued existence of a civilized and engaged humanity (Arendt, 1998). While she was concerned about environmental degradation (Canovan, 1998), the concern of much importance today, Arendt was primarily considering the durable human and cultural—rather than natural—world when writing this passage. By “ruin,” Arendt was referring to the petrification of human knowledge so that it holds no meaning and prevents opportunities for critical judgment. The common world for Arendt is that which belongs to past, present, and future. Arendt also highlights other concepts by using particular language. For example, her use of the word “point” is reminiscent of the idea of the “Stopping” synergy of mindful teaching (MacDonald & Shirley, 2009), as a particular moment removed from the unrelenting flow of time. In addition, that we “decide” connotes the idea that there is deliberation, thought, judgment, awareness, and mindfulness in our practice, rather than floating by on assumptions.

What is particularly interesting is that Arendt furnishes a series of tensions between past and future, love and responsibility, ruin (petrification) and the unforeseen. To this list, I also add the tension between the experiences and needs of the student and the discipline of science. A humanistic approach to science education openly and mindfully engages in the exploration of these tensions. In addition, borrowing from a more critical strand of scholarship, a research agenda through the humanistic approaches to science education, because of the emphasis
on the human and the meaningful, “…may offer dignified, nuanced portraits of social actors; the historical constraints we encounter; and the spaces available for history making, improvisation, and change in the way we conceive of teaching students from nondominant communities, as well as their potentials” (Gutierrez & Vossoughi, 2009). Therefore, the criteria that I use for identifying humanistic approaches to science education include a mindful and explicit exploration of the tensions outlined above and the valuing of the human actors in both the research and in the science.

In surveying the literature for indications of these criteria, I identified three closely related pathways through science education: Liberal, Renewal, and Cultural-Progressive (see Figure 2.1 and Table 2.1). While there are certainly areas of overlap between these three Pathways, they are distinct in their general focus and approach. They provide different models in their approach to understanding the human role in science education and the ways that meaning is negotiated. I will argue at the end of this section that in order to provide an experience in science education that allows for the negotiation of meaning in its fullest sense, we need to draw upon all three of these Pathways in considering curriculum and pedagogy in the science classroom. In exploring these Pathways, for each I ask: What are the pathway’s implications for science education as a field? What do teachers need to know in order to follow this pathway? What do students experience when following this pathway?
Figure 2.1. Humanistic Pathways in Science Education.
Table 2.1. The Humanistic Pathways in Science Education

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<th><strong>Liberal</strong></th>
<th><strong>Renewal</strong></th>
<th><strong>Cultural-Progressive</strong></th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Based on the idea that knowledge brings freedom to the individual. Recognizes science as a discipline and encourages a metawharness of science through the study of philosophy of science, history of science, and scientific argumentation.</td>
<td>Brings in approaches from other (non-scientific) philosophical streams of thought and ideas of behavior. Places value on the experience of students as a way to gradually enter the practice of science. Practical reasoning, Continental phenomenology, Deweyan pragmatism, and Gadamarian hermeneutics have been brought to bear on science education.</td>
</tr>
<tr>
<td>What do teachers need to know?</td>
<td>Liberal</td>
<td>Renewal</td>
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<td>Teachers need to understand the history and philosophy of science, the limits of science, the relationships between the scientific enterprise and the development of society and social structures, and the ways that scientific argumentation is employed as a tool for advancing scientific understanding.</td>
<td>Teachers need to have a deep understanding of scientific concepts as well as knowledge of a variety of philosophical approaches. They must also be willing to listen to and understand the lifeworlds, backgrounds, and experiences of students.</td>
<td>Teachers need to be aware of current events and contemporary scientific issues in society, and understand the cultural and linguistic backgrounds of their students and how that background influences how one approaches natural phenomena. They must, in a way, act as an anthropologist in the science classroom.</td>
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<table>
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<tr>
<th>What do students experience?</th>
<th>Liberal</th>
<th>Renewal</th>
<th>Cultural-Progressive</th>
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<tbody>
<tr>
<td>Students become “meta-aware” of the scientific enterprise and engage in deep and complex levels of critical thinking, and understand science as a human enterprise.</td>
<td>Students engage in deep reflection as they make sense of science within the framework of their own experiences, sense, and sensibilities.</td>
<td>Students consider and participate in the interface between the scientific and the political, and their existing culturally-embedded ways of knowing nature are valued, promoting identity development, becoming partners in the educational process.</td>
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**Liberal Humanistic Pathway.** The Liberal Humanistic Pathway is based on the idea that greater knowledge brings freedom and independence to the individual. This is most in line with the emphasis on the individual in Donnelley’s approach to humanizing science education (Donnelly, 2004). It is also most in line with the classical and traditional humanist ideal of a disciplined approach to study and scholarship, both in terms of delineating science as a discipline in education (as opposed to history, mathematics, English, etc.) and in terms of developing a disciplined and thorough “meta-awareness” of science. While it may seem like a
modern instantiation of Bacon's “Nam et ipsa scientia potestas est,” this pathway involves an awareness that a narrow definition of knowledge cannot provide. Areas of inquiry include two main strands: exploring the nature of science and emphasizing scientific argumentation.

The nature of science approach in science education is aimed at understanding the disciplinary boundaries and characteristics of the scientific enterprise, as well as understanding its historical and cultural embeddedness (W. F. McComas et al., 1998). This approach takes a decidedly historical and philosophical approach to teach about the workings and practices of science (Abd-El-Khalick, 2005; Davson-Galle, 2004; W. McComas, 2008). The scientific argumentation strand emphasizes the social nature of science, that scientific claims are made and evaluated by people within the scientific enterprise (Berland & Reiser, 2009; Driver et al., 2000; Duschl & Osborne, 2002). These claims are supported by empirical evidence and tying this evidence to scientific theories and understanding through reasoning and subject to peer review.

In order to teach science following the Liberal Humanistic pathway, teachers need to be aware of the cultural and historical contingencies and events that influenced and were influenced by the scientific enterprise, as well as to be aware of the workings of the scientific argumentation process. This approach to teaching seems to have been influenced by the work of Israel Scheffler (1992), mentioned previously, in that the educator needs not only to know what the
practitioner of science knows, but also the larger import, significance, and ways of translating it for a new generation of students. By learning to become “meta-aware” of the scientific enterprise, students engage in deep and complex levels of critical thinking and cognition. Towards this end, McNeill (2009) found students’ skills in writing scientific arguments did not fully develop when their teachers over-simplified the scientific argumentation concept. In addition, at least at the cognitive—if not practical—level, students come to understand science as a human enterprise.

These emphases on the historical, philosophical, human, and social processes in science are counters to the naïve empiricism and narrow instrumentalism in conventional science education. The Liberal Humanistic Pathway is rooted in the history, philosophy, and sociology of science. The next Pathway—the Renewal Pathway—takes a slightly different approach.

**Renewal Humanistic Pathway.** Rather than starting in science, the Renewal Humanistic Pathway finds existing philosophical positions and brings them to the teaching of science. Renewal Humanism should not be seen as an example of consilience, where the philosophical traditions would replace the basic rational and (broadly) instrumental character of science in an inversion of the consilience of Wilson (2003). Instead, this Pathway is more of a *rapprochement* (Scheffler, 1992, p. 385): an establishment of ties and dialogue between two fields, the various positions in philosophy and science education. In this review, I cover
four areas of philosophical inquiry that have been brought to science education: practical reasoning, Continental phenomenology, Deweyan pragmatism, and Gadamarian hermeneutics.

Brickhouse et al. (1993) advance a model of practical reasoning for science education which is derived from Aristotelian thought, American pragmatism, and Continental hermeneutics. In their conception of practical reasoning, they place judgment and competence as the core activities when considering the relationships between scientific knowledge (episteme), instrumental practice (techne), and the “realization of human well-being, which by its nature must be open to continual reinterpretation” (praxis; Brickhouse et al., 1993). In advancing this model, the authors acknowledge the attributes of science that set it apart from other disciplines—and are markers of its success—but bring other human characteristics into the consideration of science education pedagogy, curriculum, and research.

The next area of inquiry is that of Continental phenomenology, with its emphasis on lived experience. Phenomenology’s roots include the work of Dewey, Husserl, and Merleau-Ponty, each thinker providing aspects of a mainstream approach to lived experience (Dahlin, 2001). The challenge in science education that a phenomenological approach seeks to address is that of “cognitivism,” the over-reliance on abstract thought and theory at the expense of tangible experience (Dahlin, 2001; Dahlin et al., 2009; Østergaard et al., 2008). This experience is
described by the “lifeworld” of individual students; teachers must have a deep appreciation for how students experience the world, and provide opportunities for learning science that connect with this experience through the stimulation of the senses as well as the mind (Dahlin, 2001; Dahlin et al., 2009). The proponents of this approach do not jettison science “content” or scientific theories in order to accommodate “experience.” In fact, a phenomenological approach considers the teacher, the students, and the subject as a “triadic whole” (Østergaard et al., 2008, p. 94). A phenomenological approach is intended to ease the transition between the experiential lifeworlds of students and the “idealizations of scientific theories” (Dahlin, 2001, p. 453).

The adherents of an approach to science education based in the works of John Dewey, who has a serious reputation as an American pragmatist as well as a scholar of Continental philosophy, advocate a framework similar in tone and meaning to the phenomenological model outlined above. Dewey believed that in the dualism between the child and the curriculum, the educational system tends to favor the curriculum throwing the process of education out of balance. Dewey’s goal was to bring a sense of balance to the educative process, not to wrench the process in the other direction (unlike many radical progressive educators; Kruckeberg, 2006). Similar to the Continental form of phenomenology, an emphasis is placed on the experience of the student: the role of the teacher becomes to evoke meaningful aesthetic experiences in the science for students.
which “...emerges from the participation of students with the environment as they create as they become involved in the drama of its plot” (Wong et al., 2001, p. 322). Science content and knowledge are important in a Deweyan-influenced approach, but there is also an emphasis on the aesthetic nature of science education as well (Girod & Wong, 2002; Wong, 2007).

Lastly, philosophical hermeneutics has been a source of inspiration for the renewal of science education. Hermeneutics—named after the Greek god Hermes, the messenger of the gods—is the methodological study of “texts” for personal meaning, although it has also been applied to situations and events (Taylor, 1990). One particular approach, inspired primarily by the work of Gadamer (2004), seeks to place the act of interpretation in the learning and teaching of science. In doing so, the approach emphasizes the historically- and culturally-embedded nature of science, delineating science’s boundaries, and placing meaning at the center of learning (Eger, 1992, 1993a). It is, overall, a focus on language as the medium of discourse, and replaces the widely-accepted notion of scientific misconceptions (Smith, diSessa, & Roschelle, 1993) with the idea that students of science bring preconceptions about the way the natural world works with them to the learning experience (Eger, 1993a). Unlike misconceptions, preconceptions are not ideas to be replaced, but starting points in the interpretive process as students compare established scientific understandings, empirical evidence, and their own thinking about natural phenomena, learning to communicate about the phenomena with
greater specificity and understanding (Eger, 1993a, 1993b; Gadamer, 2004). This approach encourages intellectual and personal reflection that tends to combine practical reasoning with the lifeworld and experiential nature of the phenomenological and Deweyan-influenced approaches.

Teaching following the Renewal Humanistic Pathway requires that teachers both have a deep understanding of scientific concepts, an appreciation for and a willingness to explore the variety of philosophical approaches described here, and a willingness to listen to and understand the lifeworlds, backgrounds, and experiences of their students. Students experience a deeply reflective approach to science, as they learn to make sense of science within the framework of their experiences, senses, and sensibilities, gradually engaging in the practice of science.

The Renewal Humanistic Pathway is different than the Liberal Humanistic Pathway in that it does not start in science and instead draws upon philosophical approaches as a gateway to understanding the sciences and the natural world. The last Pathway, the Cultural-Progressive Humanistic Pathway, looks primarily to cultural studies as a guide rather than philosophy.

**Cultural-Progressive Humanistic Pathway.** The Cultural-Progressive Humanistic Pathway in science education is different than the two previously mentioned Pathways in that it builds upon the fields of cultural and critical studies, linguistics, sociology, anthropology, and critical studies. The Cultural-Progressive Pathway is often inherently political in nature, while the other two are
not necessarily as embedded in the political sphere. Similar to other pathways there is an enduring concern of the human aspects of science. In this Pathway’s quest for equity for and inclusion of marginalized groups, there tends to be a greater push against the ontological structure of science itself in order to include other explanations of the natural world as equally valid in science. Science is positioned as “Western” (Aikenhead, 2005, 2007; O. Lee, 1999) or “European” (Lemke, 2001), advancing its own set of conceptions and practices at the expense of other forms in the understanding of the natural world. The underlying impetus for the Cultural-Progressive Pathway may be found in the following passage by Lemke (2001):

...[W]e should give students opportunities to change their minds [about how to think about nature], but we should not do so unaware that we are thereby inviting them to join a particular subculture and its system of beliefs and values. We must also stop and consider whether we are, perhaps unnecessarily, making the price of admission to science the rejection of other essential components of students’ identities and values, the bonds that link them to other communities and cultures. We cannot afford to continue to believe that our doors are wide open, that admission is equally free to all, that the only price we ask is hard work and logical thinking. We need to understand how the price is reckoned from their side of the differences that separate us. We also need to critically reexamine whether the particular view of scientific rationality we offer is an idealization, or a travesty, of the true scientific spirit. (Lemke, 2001, p. 312)

The Science-Technology-Society (STS) strand came to the fore as a major science education reform effort in the 1980’s (Yager, 1996) after its genesis in the 1960’s and is based on four central purposes:

1. *Science for meeting personal needs*, preparing students to improve their own lives through science;
2. *Science for resolving current societal issues*, to prepare students to act as informed citizens concerning science-related issues;
3. *Science for assisting with career choices*, providing students with an awareness of careers in the science and technical fields;
4. *Science for preparing for further study*, so that students can move on to higher and deeper levels of scientific study. (Yager, 1996, pp. 5–6)

According to many of its adherents, “...the highest goal of an STS education [is] social action” (deBoer, 2000, p. 588), in other words, the ability to use knowledge of science to address societal and science-related issues as active and engaged citizens. The emphases on the “every day” problem-solving aspects of science and on the scientifically-educated and engaged citizen has persisted through a number of forms and research efforts (Aikenhead, 2004, 2005; Hurd, 2000, 2002; S. Lee & Roth, 2003). While the ideals of STS have been written into major science education reform documents, these documents nonetheless largely promote a naïve empirical and narrowly instrumental approach to science education by laying out the “key concepts and methods that students should know” (M.
Eisenhart, Finkel, & Marion, 1996, p. 266) through their affiliated standards. The STS approach provides theoretical and historical grounding for the other two strands of the Cultural-Progressive Humanistic Pathway in science education.

Rather than starting from the applications of science in societal sphere, the second strand, Culture Studies in Science Education, approaches science education from the perspective that understanding the natural world is a culture-based activity; therefore, what we typically refer to as science is a culture-bound activity that can act to prevent students with non-European cultural and linguistic backgrounds from fully understanding science (Costa, 1995). Lee and Fradd (1998) and Moje, Collazo, Carillo, and Marx (2001) position these diverse cultural and linguistic backgrounds as “funds of knowledge,” that students should be encouraged to draw upon as they learn the new linguistic and cultural conventions of science, rather than be expected to jettison these understandings when they enter the science classroom. Others (e.g., Hodson, 2001; Ogawa, 1995; Snively & Corsiglia, 2001; Stanley & Brickhouse, 1994, 2001) take a further step and assert that Western/European science should not be taught at the expense of other cultural ways of investigating nature.

The Critical Studies in Science Education strand emerges from critical, poststructuralist, and feminist theories in the social sciences with working toward equity and social justice as its aim (Aikenhead, 2005; O. Lee, 1999). This strand, combining aspects of both STS and Culture Studies, is overtly political and views
traditional science education with suspicion as an instrument of Western hegemony and a partner in globalization (Calabrese Barton, 1998, 2003; Calabrese Barton & Yang, 2000; Fensham, 2009; Hodson, 2003). The political context influences both the pedagogical and curricular approaches of this strand. For example, from a curricular perspective, Hodson (2003) identifies seven “areas of concern:” human health; food and agriculture; land, water, and mineral resources; energy resources and consumption; industry; information transfer and transportation; and ethics and responsibility. Calabrese Barton (2002) advances the idea that science education in urban settings should focus on issues of social justice and helping students develop a “sense of place,” rather than focusing on abstract and general scientific concepts. The idea of “critical science agency” is a strong driver in this strand, in which student identity development and the strategic use of knowledge resources form the core of an iterative and highly student-empowering learning process (Basu & Calabrese Barton, 2007, 2009, 2010; Basu et al., 2009).

In following the Cultural-Progressive Humanistic Pathway in science education, a teacher needs to have a grasp of current events and the relationships between science, policy, and societal concerns. A teacher would also need to understand the backgrounds of her students from cultural and linguistic perspectives, and how these backgrounds influence how one explores and organizes nature and natural phenomena. Hodson (2001, 2002) positions the work
of the teacher as similar in scope and skills to that of an anthropologist or other cultural worker. Students in this Pathway are provided the opportunities to consider science within a societal and political frame, and granted the power to participate in the political sphere to make decisions which have a lasting impact on themselves and their communities based on scientific undertakings. Since their existing “funds of knowledge” and culturally-embedded ways of exploring and organizing nature are both acknowledged and valued, and concern is placed on their identity development, students become partners in the educational process.

The Cultural-Progressive Pathway focuses largely on the political, cultural, and critical aspects of science education. This sets it apart from the other two Pathways, which focus on either the domain of science and the liberation of the individual (the Liberal Pathway) or the experience of individuals in the natural world (the Renewal Pathway). The next section will examine how the three Humanistic Pathways in science education can be considered together.

**The Case for Pluralism in Humanistic Science Education.** Each of the Humanistic Pathways in science education—Liberal, Renewal, and Cultural-Progressive—avoid the assumptions of naïve empiricism and narrow instrumentalism, and in their own ways acknowledge and explore the tensions highlighted in this review of the literature. When considering the negotiation of meaning within an approach to science education, it is important to remember that meaning as a construct is complex and layered (Shore, 1991). In its
negotiation around the science curriculum between students and teachers, one needs to provide opportunities for different meanings to be expressed and negotiated. Therefore, in this research I do not advocate for the adoption of one particular Humanistic Pathway. Instead, I advocate for a pluralistic approach to allow for the full range of meanings to be negotiated.

In developing the activities that will serve as opportunities for dialogue and negotiation in this research, I will draw upon all of these three Pathways, although primarily upon the Cultural-Progressive Humanistic Pathway, especially with its emphasis on valuing the voices of students and their home communities. The Liberal Humanistic Pathway, especially its scientific argumentation strand, has been more widely accepted into the general science curriculum than the other two Pathways, so I will not be as diligent to draw upon this approach. The Renewal Humanistic Pathway requires a much more philosophical mindset on the part of the teacher, one that draws upon Continental thinking, and would require a much more in-depth educational commitment on the part of the teacher than can reasonably be expected for this research project. Therefore, while the Cultural-Progressive Humanistic Pathway will be represented most prominently in this research, from a broader policy and curriculum development perspective, a pluralistic approach where all three Humanistic Pathways in Science Education are exemplified is the ultimate goal.
Meaning, Deliberation, and a Humanistic Approach to Science Education

Given that the Humanistic Approach to science education frames my curricular and pedagogical work, and figured worlds frame much of my research efforts, it is important to consider them in light of each other. The figured worlds framework is in line with the Humanistic Approach to science education in that it places the emergence of identity and meaning at its core. Identity and meaning are indeed what are figured through the act of practicing and living in the world.

In order to develop a more robust and thorough theory, I will now play the empirical and philosophical frameworks off one another. As noted earlier, it is important in formal education to account for the growth and development of the individual learner (Erickson, 1982); I also noted the idea of the “humanistic coefficient” (V. Turner, 1974), which is based upon the lived experience of mindful and aware individuals in a social setting, rather than simply establishing patterns of practice. The consideration of the individual and the humanistic coefficient are essential in teasing out and understanding the deliberative and historic nature of figured worlds.

Furthermore, figured worlds, as an empirical framework, lacks an inherent way to evaluate the “ends” of the figured world: it provides little guidance for judging the quality of the world and its goals. When considering a reflective and deliberative approach to figured worlds, the Humanistic Approach to science education and figured worlds can complement one another, with the Three
Pathways providing guidance for exploring what a *good* figured world—such as the science classroom—could emerge. This is not to say that there is one static picture of a good figured world, but instead a figured world which strives towards building capabilities and justice for all its inhabitants embedded within a broader diverse and pluralistic world (Delors, 1996; Noddings, 1995, 2010; Nussbaum, 1997, 2010), recognizing that “...true growth [within the figured world of the classroom] is conducive to further growth” (emphasis added; Alder, 2002, p. 243). Rather than providing a set and static endpoint, the humanistic pathways provide potential trajectories toward a set of larger aims.

When considering the figured world of the science classroom in light of the aims gleaned from a humanistic approach to science education, it is necessary to recognize the very real challenges to these approaches. For example, Carlone, Haun-Frank, and Webb (2011) found that, “...it is much easier to 'do school science,' to (re)create figured worlds of science learning, in ways that reproduce the status quo” (pp. 481-482) rather than to create a more inclusive and equitable experience for students and teachers alike. A figured world cannot be simply willed into a particular shape; instead, the emergence of “new” figured worlds in the science classroom require “...constant maintenance, vigilance, persistence, endurance, and commitment” (Carlone, Haun-Frank, & Webb, 2011, p. 482). This research project is one small step and effort to provide insight into what can be found and shaped in the science classroom and curriculum.
This review of the literature described the conventional approach to science education in terms of its two problematic assumptions, naïve empiricism and narrow instrumentalism, and how they impact educational change and the negotiation of meaning. These assumptions of the conventional curriculum hold the conventional curriculum in place, and impede the negotiation of meaning around the science curriculum. I then provided an alternative, the Humanistic Approach to science education, and its three Pathways—Liberal, Renewal, and Cultural-Progressive Humanism. In combination, these three Pathways provide the time, place, and impetus for the negotiation of meaning around the science curriculum within the science curriculum. These three Pathways provide guidance in terms of developing the activities for this research project. Furthermore, these Pathways provide the pedagogical and curricular context for investigating my overarching research question, *What are the relationships between meaning and science that surround the science curriculum for students and teachers?* In the next chapter, I will describe this research agenda and the methods for exploring this agenda in detail.
CHAPTER THREE: METHODS

This research draws upon the ethnographic traditions in the field of the anthropology of education. Anthropology provides promising epistemological, pedagogical, and methodological perspectives in science education research (Hammond & Brandt, 2004). In addition, anthropology can be seen as the “uncomfortable science” (Firth, 1981, p. 198), providing a way to illuminate relationships and processes that may not have been “accounted for” in other research traditions. Lastly, the figured world framework from which I draw is itself deeply grounded in anthropology.

Participants

I worked with a middle-track high school biology classroom comprised of a range of students in terms of prior achievement, home languages and cultures, and socioeconomic class. The district is located in Cotstead\(^2\), an inner-suburb about ten miles west of a large New England city. Cotstead hosts a large number of technology and biotechnology companies in expansive office parks along a stretch of an interstate highway, although residents of the city are greatly diverse with a large number of immigrant and blue collar families compared to its more affluent neighboring towns and cities. A school of about 1,400 students, about 12% of students at Cotstead High are African-American, 25% Hispanic, 5% Asian, and 0.4% Native American, while the remaining students are of White European

\(^2\) The name of the city and all names of participants are pseudonyms.
background. The teacher, Ms. Stoneham, is a woman for whom teaching is her second career: she previously worked as a histologist for 9 years in a hospital in the larger New England city. This aspect of her personal history is significant for this line of research, as she has experience and training as a scientist. At the time of this research, she has been teaching high school science for 7 years and science at the middle school level for 9 years. She was completing coursework for her Masters degree in education through a local state college. I also closely followed and formally interviewed six students, four girls (Kimberley, Leah, Debra, and Margarid) and two boys (Gabriel and Matt). These students were selected in consultation with Ms. Stoneham in order to represent a range of experiences and cultural and linguistic backgrounds, mirroring the diversity of the class. These six students were identified by Ms. Stoneham as informants who would provide thoughtful responses while representing a range of achievement levels in the class, languages, and backgrounds. Kimberley and Leah are from English-speaking families of European backgrounds. Debra is a temporary resident of the United States from Brazil. Her family speaks Portuguese, and she is receiving support from the school as an English language learner. Margarid’s family speaks both Armenian and English at home, and her parents are from Armenia and Lebanon. The families of Gabriel and Matt speak Spanish at home: Gabriel’s parents are from Puerto Rico, and Matt’s parents are from Guatemala.
Time Frame and Units of Study

I was involved in classroom activity for three full units of study during the Genetics and Biodiversity topic, which translates to approximately six weeks in length. The units which the class covered during this time period were:

1. Protein Synthesis
2. Mendelian Genetics
3. Evolution

I divided the research into three stages, summarized in Figure 3.1. I provide a broad brushstroke of the research activities here and develop them further in the Data Collection section below. During Stage 1, I spent time in the classroom every day as a participant-observer. Ms. Stoneham and I met during this stage and we worked on the design and framing of the activities. Furthermore, I conducted the early-stage formal interviews with Ms. Stoneham (Appendix A) and six students (Appendix B). During Stage 2, I spent time in the classroom as a participant-observer and discussed events and occurrences informally with the teacher and students. The activities were enacted during this stage of the research as well. In order to help facilitate the special activities designed in conjunction with this research, I acted more as a co-teacher during the specific activities. Lastly, during Stage 3, I conducted the late-stage interviews with the teacher (Appendix C) and the six students (Appendix D), and continued to observe the day-to-day classroom activities and interactions.
Activity Design

In order to help bring the consideration of meaning within the figured world of the classroom to the fore, I co-designed four activities with Ms. Stoneham. These activities supplemented the existing curriculum. Students were provided with opportunities for guided reflection on these through the reflection sheets which are a part of each activity, as well as opportunities for reflection with less guidance through class discussions preceding and following the completion of each activity.

From a researcher’s perspective, the activities also provided an opportunity for collecting data in order to better understand the kinds of meanings that emerged from completing the activities and engaging in reflection. The activities enabled me to gather information in order to provide further guidance for teachers and curriculum developers for including similar concepts and activities in the classroom and the science curriculum. As such, the research questions that most clearly guided the design and evaluation of the activities are the second (What are the meanings that arise when students are provided the structures and activities to explicitly negotiate meanings around the science curriculum?) and third (How can teachers and curriculum developers use these processes of meaning negotiation to understand students in terms of where they are, where they have been, and how to guide them in the future?) sub-questions. In partnership with the teacher, we
collaborated together to determine the form of these activities, the way the activities were framed, and the value placed on their enactment.

These activities were intended to provide the time, space, and structure for students to explicitly negotiate and reflect upon the meanings around the science curriculum. Similar to the idea of meaning negotiation outlined in the *Theoretical Foundations* of this proposal, these activities were intended to provide students and teachers with something to reflect on and talk about, a mediating layer between the science curriculum and the dialogue, the “It” in the I-Thou-It dialogic triad of David Hawkins (2002). In addition, these activities were intended to call attention to and authorize student’s perspectives in a broader educational structure, especially with regards to its academic and social dimensions (McQuillan, 2005).

These activities were further designed to start the journey from thinking about what science means to thinking about the role their learning plays in the communities of which they were a part and in situations they may encounter. The activities were enacted in Stage 2 of the research. *Table 3.1* provides a list of the activities discussed with my teacher partner, with reference to the design approaches as outlined by Levinson and Brantmeier (2006) discussed in the *Theoretical Foundations* section of this proposal as well as the Humanistic Pathways described in the *Literature Review*. 
<table>
<thead>
<tr>
<th>Research Phase</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research Activities</strong></td>
<td>Drawing Science in Action #1&lt;br&gt;Gallery Walk #1&lt;br&gt;Role Play Activity</td>
<td>Influences on Science Card Sorty/Interviews&lt;br&gt;Stories of Science in Action/Interviews</td>
<td>Debra Interview&lt;br&gt;Matt Interview&lt;br&gt;Last Teacher Interview</td>
</tr>
<tr>
<td><strong>Classroom Events</strong></td>
<td>DNA/RNA Quiz</td>
<td>High Stakes Exam in English Language Arts</td>
<td>Gabriel Interview #2&lt;br&gt;Margaret Interview</td>
</tr>
<tr>
<td><strong>Extra-Classroom Events</strong></td>
<td>Visit by Museum Scientist</td>
<td>Spring Break</td>
<td>Day of Silence for Gay Rights</td>
</tr>
<tr>
<td><strong>Month</strong></td>
<td>March</td>
<td>April</td>
<td>First Week of May</td>
</tr>
</tbody>
</table>

**Figure 3.1.** Detailed Timeline of Classroom, School, and Research Activities.
The protocols for the activities can be found in *Appendices E-H*. During the discussion portions of these activities, students were asked to think about and discuss the design questions which guided each activity. Ms. Stoneham and I arrived at these questions so that the language was consistent with the comprehension level of the class. In addition, Ms. Stoneham and I discussed and developed the appropriate framing of the activities so that they flowed appropriately and were incorporated within the expectations of day-to-day classroom activity.
Table 3.1. Activity structures.

<table>
<thead>
<tr>
<th>Guiding Design Question</th>
<th>Potential Activity Structure</th>
<th>Theoretical Framework</th>
<th>Humanistic Pathway(s)</th>
<th>Design Approaches</th>
<th>Context/Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the place of learning science as I live my life?</td>
<td>“Gallery Walk” where students respond to modified versions of Klafki’s questions concerning curriculum. (Appendix E)</td>
<td>Klafki’s Questions for a Didaktik Analysis (Hudson, 2003; Klafki, 2000)</td>
<td>Liberal, Renewal</td>
<td>Reflective, Cooperative, Exemplary</td>
<td>Mendelian Genetics: 1/3 of the way through the unit Evolution: 2/3 of the way through the unit</td>
</tr>
<tr>
<td>What is my place in the larger narrative of scientific discoveries and scientific communities?</td>
<td>“Role Play” where students participate in a role play concerning a public aspect of science content. (Appendix G)</td>
<td>Role play of controversial public issues in science (Burton, 1997; Duveen &amp; Solomon, 1994)</td>
<td>Liberal, Cultural-Progressive</td>
<td>Simulative, Cooperative, Exemplary</td>
<td>Mendelian Genetics: 2/3 of the way through the unit Evolution: 1/3 of the way through the unit</td>
</tr>
<tr>
<td>Guiding Design Question</td>
<td>Potential Activity Structure</td>
<td>Theoretical Framework</td>
<td>Humanistic Pathway(s)</td>
<td>Design Approaches</td>
<td>Context/ Timeline</td>
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<tr>
<td>What is the place of science in what my communities expect of me?</td>
<td>“Framing Science PSA” where students frame a scientific issue for their community and create storyboards of public service announcements. (Appendix H)</td>
<td>Communicating and Framing Science (Nisbet &amp; Scheufele, 2009)</td>
<td>Cultural-Progressive</td>
<td>Simulative, Cooperative, Connective, Reflective</td>
<td>Mendelian Genetics: End of the unit Evolution: End of the unit</td>
</tr>
</tbody>
</table>

**Gallery Walk.** The Gallery Walk activity (Appendix E) was based on a similar activity initially developed by Price and McNeill (2010). This activity provided students with a translated and modified set of questions based on Klafki’s Questions for a Didakik Analysis (Hudson, 2003; Klafki, 2000). While Klafki’s Questions were originally intended to provide a structure for teachers when selecting curriculum materials and considering pedagogical strategies, it has also been found to provide a foundation for student reflection (Price & McNeill, 2010). The original questions and the questions in their operationalized forms can be found in Table 3.2. After designing posters in response to the questions in small groups, students had the opportunity to see other posters and engage in dialogue as a gallery walk.
Table 3.2. Klafki’s questions for a Didaktik Analysis

<table>
<thead>
<tr>
<th>Original Questions</th>
<th>Operationalized Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I</strong> What wider or general sense or reality does this content exemplify and open up to the learner? What basic phenomenon or fundamental principle, what law, criterion, problem, method, technique, or attitude can be grasped by dealing with this content as an “example”?</td>
<td>What was the <strong>BIG IDEA</strong> that you learned while studying about [Mendelian genetics/evolution]?</td>
</tr>
<tr>
<td><strong>II</strong> What significance does the content in question, or the experience, knowledge, ability, or skill to be acquired through this topic already possess in the minds of the children in my class? What significance should it have from a pedagogical point of view?</td>
<td>How did this <strong>BIG IDEA</strong> relate to something that you already knew?</td>
</tr>
<tr>
<td><strong>III</strong> What constitutes the topic’s significance for the children’s future?</td>
<td>How might you use this <strong>BIG IDEA</strong> in the future?</td>
</tr>
<tr>
<td><strong>IV</strong> How is the content structured (which has been placed in a specifically pedagogical perspective by Questions I, II, and III)?</td>
<td>How did the readings and activities about [Mendelian genetics/evolution] convey this <strong>BIG IDEA</strong> to you?</td>
</tr>
<tr>
<td><strong>V</strong> What are the special cases, phenomena, situations, experiments, persons, elements of aesthetic experience, and so forth, in terms of which the structure of the content in question can become interesting, stimulating, approachable, conceivable, or vivid for children of the stage of development of this class?</td>
<td>How did the readings and activities about [Mendelian genetics/evolution] make the learning interesting and fun? Did you learn anything surprising?</td>
</tr>
</tbody>
</table>

This activity drew primarily upon the Liberal and Renewal pathways of the Humanistic Science Curriculum. In terms of the Liberal pathway, this activity encouraged the development of critical thinking skills and metacurricular awareness. From a Renewal viewpoint, Klafki’s Questions are a renewed contemporary manifestation of Bildung—anchored firmly in German Continental philosophy and thought—combined with a critical-constructivist perspective (Klafki, 2000). In addition, from a design approaches standpoint, the aim of this
activity was to encourage reflection and cooperation between students to develop the posters.

**Drawing Science.** The Drawing Science activity (Appendix F) provided students with the opportunity to reflect on what “doing science” looks like. Students were asked to draw what doing science looks like. The illustrations were then passed around to groups in the class, and the students were asked to analyze the pictures for similarities, differences, and patterns. The activity was based on research conducted by Lifford et al. (2000) who asked students to draw pictures in order to promote reflective learning, adapted for the science classroom. Furthermore, Haney et al. (2004) found that drawing activities are effective in promoting student voice in educational change efforts.

This activity primarily drew upon the Cultural-Progressive pathway, with its strong emphasis on promoting student voice and its student-centered approach. From a design perspective, this activity was intended to promote reflection on science as a human activity, provide exemplary opportunities for considering the scientific enterprise from a position of power, and an occasion to cooperate in small groups to analyze the drawings.

**Role Play.** The Role Play activity (Appendix G) provided a structure for students to consider the social and controversial aspects—the human aspects—of the science content they were studying. Based on the prior research of Duveen and Solomon (1994) and following the framework developed by Burton (1997),
students took on a variety of roles in a scenario based on the impact of science on society, namely the question of whether or not a dog genetics research center should be built in Cotstead. The scenario connected with a video they had watched on the topic (*Science of Dogs*, 2007). Students switched roles at intervals so that they experienced the scenario from multiple perspectives.

This activity drew primarily upon the Cultural-Progressive pathway in that it promoted a view of science which is culture-bound and historically-embedded, as well as taking a decidedly student-centered approach to learning. However, it also promoted critical thinking and perspective-taking, therefore representing the contemporary manifestations of the Liberal pathway’s “meta-awareness” of the discipline of science. From a design approaches perspective, the intent of this activity was to provide a historically-based simulation of science, and to provide a set of different perspectives and pedagogical approaches to learning compared to the typical science education experience. Students cooperated to fill the roles and developed a narrative based on the scenario prompts. As the students and teacher seemed to arrive at consensus early and easily, I took on multiple roles in the role play in order to extend and deepen the dialogue.

**Framing Science Public Service Announcement.** The Framing Science Public Service Announcement activity (*Appendix H*) provided students the opportunity to reflect on the way that both genetics and evolution impact their communities and how they can “translate” the science into the discourse of non-
scientific communities. They were provided with a set of “frames” that are used in public discourse when discussing science, such as “Social Progress,” “Scientific/Technical Uncertainty,” and “Pandora’s Box/Frankenstein’s Monster/Runaway Science” (Nisbet & Scheufele, 2009). Students were asked to create a storyboard of a Public Service Announcement (PSA) and consider which frames they will be using in their PSA and why. The teacher allowed one group who finished their storyboard early to transform their storyboards into a finalized PowerPoint presentation. Students were asked if there were other frames that they would consider using in communicating information about science to their communities.

This activity was based in the Cultural-Progressive pathway as it provided students with the opportunity to not only consider science as a culture-bound activity, but also the opportunity to consider how to translate scientific understandings so that they make sense within the cultural frameworks of their own communities. From a design approaches perspective, this activity was intended to provide students with the “authentic” task of developing a storyboard PSA (simulative) and to work together to accomplish the task (cooperative) in a novel way that allowed them to think critically about how to translate science and scientific understandings for their communities (exemplary). In doing so, they reflected on both the nature of science as well as the assumptions, languages, and expectations of their own communities.
Each activity included time and questions for reflection and discussion. Example protocols for this reflection are included in *Appendices E-H* as part of the supplementary materials for each activity. There were also opportunities for imagination in a particular sense: the start of connecting learning science with meaning and how learning connects with how students live their lives and relate to their communities. In this case, I follow Wenger’s description of imagination as “…a process of expanding our self by transcending our time and space and creating new images of the world and ourselves” (Wenger, 1999, p. 176). While these activities were not new, the combination of these activities were meant to be generative in order to stimulate dialogue and the negotiation of meaning around the science curriculum.

**Data Collection**

As noted above, I drew upon ethnographic methods for collecting data in the classroom at Cotstead High School. All observations and interviews (formal and informal) were recorded by an audio recorder and I took field notes and wrote daily research memos. I adopted a participant-observer perspective, which allowed me to meet my goal of understanding the process of meaning negotiation within the classroom, as “…the field researcher sees first-hand and up close how people grapple with uncertainty and confusion, how meanings emerge through talk and collective action, how understandings and interpretations change over time” (Emerson, Fretz, & Shaw, 1995, p. 4). The audio recordings were selectively
transcribed. As I coded my fieldnotes, I identified passages and exchanges.

Approximately 5% of the recordings of the classroom observations were transcribed based on the coding of my fieldnotes. The interview recordings were transcribed in full and coded concurrently with my notes and memos for the interviews. The data sources and data collection methods in the context of my research sub-questions are summarized in Table 3.3.

**Table 3.3. Sources and methods of collecting data.**

<table>
<thead>
<tr>
<th>Research Sub-Question</th>
<th>Data Sources</th>
<th>Approaches</th>
<th>Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do a teacher and her students describe the field in which the negotiation of meaning takes place?</td>
<td>Formal and Informal Interviews with Students and Teacher</td>
<td>Ethnographic Interviews/ Ethnosemantic Model</td>
<td>Field Notes, Memos, Audio Recordings</td>
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<tr>
<td></td>
<td>Activities</td>
<td>Participant Observation</td>
<td>Field Notes, Memos, Audio Recordings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qualitative Content Analysis (QCA)</td>
<td>Student Artifacts</td>
</tr>
<tr>
<td></td>
<td>Pile Sort</td>
<td>Non-Metric Multidimensional Scalar Analysis</td>
<td>Pile Sort Results</td>
</tr>
<tr>
<td>What are the meanings that arise when a teacher and her students are provided the structures and activities to explicitly negotiate meanings around the science</td>
<td>Formal and Informal Interviews with Students and Teacher</td>
<td>Ethnographic Interviews/ Ethnosemantic Model</td>
<td>Field Notes, Memos, Audio Recordings</td>
</tr>
<tr>
<td></td>
<td>Classroom Observations</td>
<td>Participant Observation</td>
<td>Field Notes, Memos, Audio Recordings, Class Assignments</td>
</tr>
</tbody>
</table>
The first sub-question, *How do a teacher and her students describe the field in which the negotiation of meaning takes place?*, was addressed through student and teacher interviews, classroom observations, observations of the enactment of
the designed activities, and analysis of the student artifacts created as a result of the designed activities. The observations of the activities themselves provided insight into the process of how the negotiation of meaning took place through these designed activities, while the classroom observations provided insight into this same process without these structures and activities in place. The analysis of the student artifacts, including the reflection sheets, provided data about the products of the negotiation of meaning. The interviews provided opportunities for students and the teacher to reflect on the negotiation of meaning both with and without the structures in place, and what this negotiation meant for them, how they live their lives, and how they relate to their communities. The analysis of the student artifacts, including the reflection sheets, provided data about the products of the negotiation of meaning. The interviews provided opportunities for students and the teacher to reflect on the process and the products of the negotiation of meaning, and what it meant for them. The pile sort activity provided a sense of the dimensions that the students saw as “doing science,” providing a shape of the field for the negotiation of meaning.

The second sub-question, What are the meanings that arise when students are provided the structures and activities to explicitly negotiate meanings around the science curriculum?, were explored through formal and informal interviews with the students and the teacher, observations of the enactment of the designed activities, and analysis of the student artifacts created as a result of the designed
activities. This sub-question is primarily evaluative in nature, used to explore how the activities were used and what meanings were generated and discussed. The observations of the activities themselves provided insight into the process of how the exploration of meaning took place through these designed activities. The rank order sort provided a sense of the values that students and Ms. Stoneham placed on a variety of influences on science and science education, both inside and outside the classroom.

The third sub-question, *How can teachers and curriculum developers use these processes of meaning negotiation to understand students in terms of where they are, where they have been, and how to guide them in the future?*, was addressed through the modification and design of the activities in partnership with the teacher, student and teacher interviews, classroom observations, observations of the enactment of the designed activities, and analysis of the student artifacts created as a result of the designed activities. The co-design process with the teacher provided insights into the process of how the teacher prepares her materials to connect with her students’ lives and experiences, and the analysis of the modified activities provided a material representation of this process. The observations of the activities themselves provided a look into the process of how the negotiation of meaning takes place through these designed activities, while the classroom observations provided insight into this same process without these structures and activities in place. The analysis of the student artifacts, including
the reflection sheets, provided data about the products of the negotiation of meaning. The interviews provided opportunities for students and the teacher to reflect on the process and the products of the negotiation of meaning, and what it meant for them.

In developing the activities with the teacher during Stage 1, I met with the teacher. Together we designed the activities and developed the framing around them so that they were integrated into the flow of the classroom. During this meeting, I took field notes and recorded the sessions with an audio recorder. I also conducted scheduled formal interviews with Ms. Stoneham and six students. The interview protocols can be found in Appendices A-D.

I sat in on the classroom during Stages 1 and 2, completed the in-class activities and homework, and participated in small group activities as a participant-observer. During these observations, I sat towards the back of the classroom, although I placed myself in small groups so that I was with at least one of the students I was closely following and interviewing. Participant observation provided a naturalistic mode of data collection for understanding the relationships between meaning and science from the perspective of the participants. The goal of participant observation is not only to catalogue and record the activities that occur in the classroom, but to be able to adopt the perspective of the participants so that the researcher can anticipate the reactions of the participants under particular circumstances and contexts (Emerson et al., 1995). I worked to gain this insight
through close observations of the workings of the classroom in real time as well as by completing classroom activities, homework assignments, and quizzes.

During the activities developed specifically for this research, I took on more of a co-teacher roll than participant-observer in order to help facilitate the activities and to extend and deepen the dialogue. I collected all student artifacts from the activities. I did not complete the activities themselves as I did in regular class time. Since most of the activities involved a small group component, I chose a particular group to closely observe as I could. I recorded this group with an audio recorder and I took field notes. I supplemented participant observations with formal and informal interviews. The formal interviews provided background information and further insight as to who the social actors were and how they viewed the relationships between meaning and science. Figure 4 provides a map of how specific questions in the interview protocols connect to the research questions. The section and question numbers refer to the interview protocols found in Appendices A-D. The interviews conducted in Stage 1 of the data collection are primarily exploratory in terms of understanding the negotiation of meaning process, and most closely align with the overarching research question and the second sub-question. The interviews conducted in Stage 3 are more evaluation-focused, and are therefore more closely aligned with the first and third sub-questions.
I also asked the students in the class to participate in a pile sort activity and a rank order activity, both of which are drawn from the field of cognitive anthropology. For the pile sort activity, I wrote up a variety of stories or vignettes describing people doing activities related to science on small pieces of paper (see Appendix I). Students were asked to place the cards into any number of related piles. When everyone had finished the task, I took a photograph of each one and uploaded the photos to my laptop. I then interviewed each student individually in turn and asked them why they placed each of the vignettes into the particular piles will looking at the digital photo of their card sort results. Later, the results of the pile sort activity were entered into ANTHROPAC (Borgatti, 1992), which provided an aggregate proximity matrix (see Appendix J). This matrix was then imported into UCINet (Borgatti, Everett, & Freeman, 2002) and a non-metric multidimensional scaling (MDS) analysis was conducted on two dimensions. The results of this analysis will be discussed in the Chapter 4, and is largely in response to the question, What are the meanings that arise when students are provided the structures and activities to explicitly negotiate meanings around the science curriculum?

With the rank order activity, I provided every student with a list of potential influences on engagement in the science classroom on small strips of paper (see Appendix K). The students were asked to put these potential influences in order from most influential to least influential. When everyone had completed
the task, I took a photograph of each one and uploaded the photos to my laptop. I then interviewed each student individually in turn and asked them why they placed each of the vignettes into the particular piles will looking at the digital photo of their rank order results. I repeated this activity with Ms. Stoneham at a different time outside of class. Later, the results from the rank order activity was imported into ANTHROPAC, which calculated a Smith's Salience Score (Smith’s S) for each potential influence, based on the mean average and frequency of being included (as some students excluded some of the potential influences) across the range of student responses. The results of this analysis are discussed in Chapter 5, and are in response to the question, How do students see these negotiations of meaning around the science curriculum, explicit and tacit, affecting how they live their lives and relate to their communities?

Lastly, I also wrote daily research memos (Emerson et al., 1995) every day that I was in the classroom. All data sources were stored and organized utilizing the Atlas.ti qualitative data analysis software. By triangulating across these data sources over time, I was able to follow the meaning negotiation process from my own participant-observer position, as well as from the perspective of the students and the teacher.

**Data Analysis and Interpretation**

The data analysis process was oriented toward “...sorting out the structures of significance... and determining their social ground and import” (Geertz, 1973, p.
9). As uncovering meaning requires both careful observation and interpretation (Kvale, 1983), these modes of analysis provide a robust theoretical grounding and practical procedures for exploring the negotiation of meanings around the science curriculum in the classroom. In conducting the analysis, I drew upon a two-pronged approach highlighted by Howe and Eisenhart (1990).

<table>
<thead>
<tr>
<th>Research Questions to Interview Questions</th>
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<tbody>
<tr>
<td>What are the relationships between meaning and science that surround the science curriculum for students and teachers?</td>
</tr>
<tr>
<td>Stage 1 Teacher</td>
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<tr>
<td>Stage 1 Students</td>
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<tr>
<td>Stage 2 Teacher</td>
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<tr>
<td>Stage 2 Students</td>
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<tr>
<td>Stage 3 Teacher</td>
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<tr>
<td>Stage 3 Students</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Research Questions to Interview Questions</th>
</tr>
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<tbody>
<tr>
<td>What are the meanings that arise when students are provided the structures and activities to explicitly negotiate meanings around the science curriculum?</td>
</tr>
<tr>
<td>Stage 1 Teacher</td>
</tr>
<tr>
<td>Stage 1 Students</td>
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<tr>
<td>Stage 2 Teacher</td>
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<tr>
<td>Stage 2 Students</td>
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<tr>
<td>Stage 3 Teacher</td>
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<td>Stage 3 Students</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Research Questions to Interview Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can teachers and curriculum developers use these processes of meaning negotiation to understand students in terms of where they are, where they have been, and how to guide them in the future?</td>
</tr>
<tr>
<td>Stage 1 Teacher</td>
</tr>
<tr>
<td>Stage 1 Students</td>
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<tr>
<td>Stage 2 Teacher</td>
</tr>
<tr>
<td>Stage 2 Students</td>
</tr>
<tr>
<td>Stage 3 Teacher</td>
</tr>
<tr>
<td>Stage 3 Students</td>
</tr>
</tbody>
</table>

Figure 3.2. Interview questions related to research questions
First, I used the ethnosemantic model advanced by Spradley (1979) to infer cultural meanings from interview data. Spradley provides guidance through four steps of analyzing interview data: *domain analysis*, in which overarching categories of meaning are identified; *taxonomic analysis*, in which the categories of meaning are related to one another; *componential analysis*, in which distinct differences between categories of meaning are identified; and *theme analysis*, in which the categories of meaning are linked to larger and broader cultural attributes.

Spradley’s ethnosemantic approach to analyzing interviews (Spradley, 1979) brought focus to the meanings of cultural phenomena and social participation as expressed by the research participants in their own terms. This approach allowed for unpacking the meanings, both explicit and tacit, of the students and the teacher around the science curriculum. These meanings were the key to the overarching research questions as well as the sub-questions. As the analysis was first done in the participants’ own terms, this approach further authorized the perspectives of both the students and the teacher, a goal of this research project.

Second, in order to provide a contextualized, more holistic, and time-dependent analysis, I adopted a vignette analysis approach (Van Maanen, 1988), aimed at “…present[ing] the reader with the stories identified throughout the analytical process, the salient themes, recurring language, and patterns of belief linking people and settings together” (Anfara, Brown, & Mangione, 2002, p. 31).
Van Maanen’s vignette approach provides a focus on meaning in time-based contextual activity, consistent with a “natural history approach to taught cognitive learning” (Erickson, 1982, p. 150), where teaching and learning are conceptualized as verbs rather than nouns, actions and activities rather than static objects, tied directly with time in the learning process. Reflecting my research questions, I was particularly interested in the negotiation of meaning, both in typical classroom discussion and activity, as well as while the students and the teacher are engaged in the activity structures designed for this research. This mode of analysis provided an in-depth account of the processes by which meaning is negotiated.

Artifacts from activities were analyzed utilizing qualitative content analysis (QCA; Mayring, 2000). QCA provides a detailed and holistic account of the meanings which are embodied in these artifacts. Patterns both within individual artifacts and across the range of artifacts are methodologically recognized through this mode of analysis.

My theoretical framework provided further guidance in the analysis of the data. Data was coded using the Atlas.ti qualitative data analysis software over several rounds following the structure outlined by Emerson et al. (1995):

1. **Open coding** to establish broad-based patterns and themes;
2. **Writing initial memos** to begin to connect notes and data to theoretical structures;
3. **Theme selection** to prioritize and sort the data collected;
4. *Focused coding* to establish a fine-grained analysis and understanding;

5. *Writing integrative memos* to explore relationships between data, themes, and broader theory.

Over the course of the research and analysis, I consulted with my committee and followed recognized standards of quality and rigor for qualitative. I describe these standards in the next section.

**Research Quality and Rigor**

As a study drawing on ethnographic methods, I drew upon qualitative and ethnographic constructs for adhering to standards of quality and rigor (Anfara et al., 2002; Howe & Eisenhart, 1990). I worked to address issues of credibility, transferability, dependability, and confirmability (Anfara et al., 2002) with reference to the observable events and interactions, my research questions and theoretical framework (see *Table 3.4*).

**Table 3.4. Criteria and strategies for research quality and rigor (following Anfara et al., 2002).**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Strategy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credibility</td>
<td>Prolonged engagement in the field</td>
<td>Participant observation data collection over two full curriculum units.</td>
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<tr>
<td></td>
<td>Peer debriefing</td>
<td>Regular consults with dissertation committee members.</td>
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<tr>
<td></td>
<td>Triangulation</td>
<td>Triangulated across data sources and multiple voices.</td>
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<tr>
<td></td>
<td>Member checks</td>
<td>Consults with teacher and students during data collection and analysis.</td>
</tr>
<tr>
<td>Transferability</td>
<td>Thick descriptions</td>
<td>Utilize thick descriptive categories (Geertz, 1973), referencing the hierarchical meaningful structures of actions, not just the actions themselves.</td>
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</tbody>
</table>
| Dependability   | Create an audit trail | Documentation of data collection and analysis process.  
|                 | Code-recode strategy | Multiple rounds of coding, with reference to data, research questions, and theoretical framework.  
|                 | Triangulation       | Triangulation across sources and voices.  
|                 | Peer examination    | Regular consults with dissertation committee members.  
| Confirmability  | Triangulation       | Triangulated across sources and voices.  
|                 | Practice reflexivity | Maintain and document my own practice and background.  

These criteria provide rigor through a methodological and transparent approach to the collection and analysis of the data. These criteria were applied to the data collected, analyzed, and discussed in the following chapters. I will provide an outline of the field as described by the teacher and her students, and then provide an overview of the ways in which meanings are found in and brought to the activities of the science classroom.
CHAPTER FOUR: MAPPING THE FIELD OF SCIENCE AND EDUCATION

As I indicated in the theoretical framework, the negotiation of meaning takes place within a field, a set of ideas, norms, and understandings. It is important, therefore—and it is the purpose of this chapter—to identify how the teacher and her students define science, education, and the relationships between the two in a conceptual sense in order to provide a fuller understanding of the negotiations of meaning which takes place within and around these categories. In this chapter, I will provide an outline of the boundaries and shapes of the cultural domain (Borgatti, 1994) of science and science education gleaned from interviews, activity artifacts, and classroom observations. I will first describe Ms. Stoneham’s description of the domain of science and then transition into her analysis of the relationships between science and science education. I then bring in student voices, and their descriptions of the domains of science education and then, more broadly, science. This chapter addresses the question, How do a teacher and her students describe the field in which the negotiation of meaning takes place?

Gaining Knowledge: Ms. Stoneham’s Perspective on Science

Several days before I interviewed her for the first time, Ms. Stoneham agreed to my offer to provide her with my interview protocol. By looking over the questions before hand, I had the sense that she felt more comfortable with the opportunity to prepare for the questions I was going to ask her and minimize the potential for surprises. Three days before I was set to sit down and interview Ms.
Stoneham for the first time, presumably after reviewing my interview protocol, she launched into a discussion with her students on the meaning of science.

Ms. Stoneham: What does the word science mean?
Eduardo: This class.
Ms. Stoneham: Does anyone remember way, way, way at the beginning of class. Does anyone remember what science?
We cleaned out our binders, so this is going to be a tough one. Science, the word, means to gain knowledge.
Remember? Gain knowledge. Yep [pointing to Margarid].
Margarid: Yeah, but you gain knowledge in every class.
Gabriel: The science of...
Ms. Stoneham: Yup, the science of, what? The science of history.
Yup, everything is kind of like a science. Right?
Margarid: But why is this class specifically called science? In this class?
Ms. Stoneham: OK, what are specifically studying in this class?
Multiple Students: Bi-ol-o-gy.
Ms. Stoneham: Which is what?
Gabriel: The study of life!
Ms. Stoneham: The study of life. Alright! And how does that apply to you?
Gabriel: We’re life.
Amanda: We’re...
Ms. Stoneham: We’re... we’re...
Amanda: Living things.
Ms. Stoneham: Right! Living things!
Gabriel: We’re life.
Ms. Stoneham: So we’re trying to make sense of...
Multiple students: Ourselves.
Ms. Stoneham: Exactly. And how we fit into what.
Rosa: The world.
Ms. Stoneham: And other living organisms. OK? And as a scientist, as in the room, here, with me, we are gaining knowledge, right? Yes?
Eduardo: Yeah.
Ms. Stoneham: Yay. We’re all so happy to have all this knowledge.
What are we looking for when we are scientists? What’s the goal of a scientist?
Henry: Information.
Gabriel: Knowledge.
Ms. Stoneham: Knowledge. Now are we looking for it in any special way?
Eduardo: No.
Margarid: No.
Ms. Stoneham: What are we looking for though as a scientist?
Henry: To learn.
Gabriel: New solutions.
Ms. Stoneham: New solutions, we’re looking for patterns, we’re looking to put answers to our questions. So we have to gain evidence and reasoning.

Before exploring this exchange and what it says about Ms. Stoneham’s views on the epistemological and ontological nature of science, it should be noted that it seemed as if over the course of this research project, she was revisiting and revising her notions of science and science education. In this analysis, there are times when both Ms. Stoneham and this researcher use the terms science and science education in the colloquial and widely accepted sense, rather than in terms of Ms. Stoneham’s specific sense described in detail below. The overlap in the use of terms is due to the nature of the reflection-in-process that Ms. Stoneham engaged in to better understand her own concepts, definitions, and experiences.

With this in mind, the short classroom exchange highlights several important things. Through the above dialogue, Ms. Stoneham set up the parameters and possibilities of the domain of science. She positioned science for her students as a process to “gain knowledge.” She further positioned the process of gaining knowledge—science—in a disciplinary-autonomous manner. In response to Margarid’s point that “...you gain knowledge in every class,” Ms.
Stoneham replied that there is “[t]he science of history. Yup, everything is kind of like a science.”

Ms. Stoneham is presenting a universally-applicable mode of gaining knowledge, irrespective of discipline and content, even though the mode itself entails particular methods and goals. The end goal, according to the teacher, is to not only develop solutions to problems, but also to “…[look] for patterns, …put answers to our questions” by “gain[ing] evidence and reasoning.” It should be noted that Ms. Stoneham has been enthusiastic and instrumental in bringing a particular pedagogical and curricular approach to scientific argumentation, which positions the process as the integration of claims, evidence, and reasoning (McNeill, 2009; McNeill & Krajcik, 2008) to not only Cotstead High School but the district as a whole. She even had a representation of the framework hanging on a bulletin board on her wall (see Figure 4.1).
Figure 4.1. Claim-Evidence-Reasoning framework on Ms. Stoneham’s board.

During our one-on-one interview later, Ms. Stoneham reiterated her definition of science, stating that “...the word ‘science’ is an umbrella for gaining knowledge on everything.” As an umbrella, she further reinforced that the methods by which that knowledge is gained is secondary to the process overall. “For me, [science is] a learning process,” she noted. “How do you learn, and why do you learn.” Finding the appropriate way to gain knowledge can be challenging for a teacher according to Ms. Stoneham, as she explained to me in an interview:

In other words, I have to understand how people learn to get them to, what actions do they need to take, to get that content knowledge. And that’s kind of ever evolving, because it takes you a while to figure out how each of your students learn. Even sometimes they don’t know how they learn, so you have to guide them in that pathway, do you use 3x5 cards, is it better if you see it, um, up on the board and see a video. Is it better that you have someone pair-share, it’s, so part of our process here for me is, when you mix science and education is, teaching them to learn how they learn and then applying it to their subject.
Science is “[t]he art of gaining knowledge,” Ms. Stoneham further explained, “but how do you get to that knowledge point, is how do you learn?” In other words, Ms. Stoneham noted that the process of science, of gaining knowledge, exhibits several characteristics. First, it is oriented towards a goal, getting “content knowledge” or reaching a “knowledge point.” Second, it is dependent upon the particularities of the individual who is following that path of gaining knowledge. Third, understanding how to gain knowledge is not necessarily innate, so that a teacher needs to “figure out” how each individual student learns and “…[teach] them how they learn.” Fourth, gaining knowledge can be accomplished through a number of strategies, such as the use of flash cards, examples on the board, or viewing a video. The “art” of gaining knowledge—of science—then is orchestrating these various aspects so that students “get that content knowledge” or “get to that knowledge point” in a variety of subjects.

In conversation, Ms. Stoneham also discusses the idea that the scientific gaining of knowledge includes some element of longevity. Such longevity is accomplished by not just a diagnosis by the teacher of individual students’ learning styles, but by raising a sense of metacognitive awareness within the student herself. “So, if I can get them to gain how they learn,” Ms. Stoneham stated, “and how they gain knowledge in a better more fundamental way, it will stick with them longer.” Through science, according to Ms. Stoneham, the student
learns how she herself learns best and what is gained or learned is not easily forgotten.

The “what” that the knowledge gaining process can be applied to is fluid. Yet Ms. Stoneham notes that some people have particular orientations that make gaining knowledge easier in some content areas as opposed to others:

...Everybody could have talents in different areas, like you could be math oriented, science oriented, art oriented, so which one of those is your particular one, one that you like, and one that you learn best in, what do you, and then taking that, once you know what type of learner you are, and where your passion is, how can you expand on that? And take it into your other subjects. Like I’m a, not very good at math, but I might be good at science, and how am I good at science, I have a logical pathway, well then I know I, this is how I learn in science, well I need to apply those in my math class, and I would have more success.

One’s orientation is influenced by one’s affinity to and success in learning particular content. Ms. Stoneham does, however, consider it a sign of success of metacognitive awareness if a way of gaining knowledge is transferred from one subject area to another. Learning how to apply one’s strength in one area, according to Ms. Stoneham, leads to success in another.

The question arises as to what Ms. Stoneham may treat as “knowledge” or “knowing.” In French a distinction is made between connaître, or “knowing something,” and savoir, that is, “knowing by experience” (F. Turner, 1986). In one particular episode in the classroom, Ms. Stoneham brought up both aspects of knowledge. In reflecting on an activity in which students cut out puzzle pieces
representing the structure of DNA and then assembled them, Ms. Stoneham said to the class:

Now if we had just gone to lecture and said here’s your notes, here’s your vocab, would you have come to this conclusion, or seen the patterns as easily as if you needed to do something. The whole point of making our puzzle was for you to experience a little bit. People who had to decipher this, Watson and Crick, they went through a very similar task as you did, except they had more complex structures of information to figure out how DNA was constructed.

In this passage, Ms. Stoneham was making a statement against a simple form of “gaining knowledge,” of “knowing something,” the savoir-type. Instead, she was setting up the importance of the connaître-type of knowing by making the point that if she had simply given the students the information, they would not have been able to see the patterns—a goal of science and scientists—if they had not assembled the puzzle themselves.

Ms. Stoneham further connected this activity to the work of real scientists, Drs. Watson and Crick, the scientists credited with successfully modeling the structure of DNA. She continued, mixing in the idea of knowledge gain of the savoir-type, which requires that knowledge be seen in an objective sense:

When we open our chapters there’s always a quick review section. Now we’re getting to the point where we’ve filled our heads with an awful lot of information, and we’re starting to forget some of it, so we have to constantly review. So for you, your homework is going to be on page 189, you’re going to write out the questions, there’s five of them, and then answer them.

Ms. Stoneham highlighted the need for review with, “...we’re getting to the point where we’ve filled our heads with an awful lot of information, and we’re starting to
forget some of it....” This statement would indicate that knowledge is gained and lost and then gained again, representative of the savoir-type. This mixing of types is not necessarily problematic, as the case can be made that both savoir and connaître are necessary for a full and deep understanding.

Thus science, according to Ms. Stoneham, is a diverse and individualized “art” of gaining knowledge. The creative and inventive art of gaining knowledge, however, also exhibits a strong element of efficiency and economy, which has an influence over how one engages with the content area. The goal is not only to reach an end point, but be able to gain understandings that “stick” with the learner as they travel their pathway and learn to apply methods of success from one subject area to another. The particularities of “science education,” the knowledge that students gain in her classroom, are discussed in the following section.

**The Subject of Science’s Process: Ms. Stoneham and Science Education**

Despite her determination to universalize science as a process of gaining knowledge independent of content, Ms. Stoneham is also careful to articulate a distinction between her class—biology—and other classes, in terms of the kind of content knowledge being gained. The kind of knowledge being gained, she reminded her students during discussion in class, is biological knowledge, about life and living things. This focus provides a venue for exploring ourselves, presumably human beings, as living things and how living things relate to one another in general.
Ms. Stoneham also points out that gaining knowledge in biology requires learning a particular set of skills. She related that,

...[I]n biology there are definitely probably a kind of like a lot of subsets of skills you have to have to gain your overall knowledge. You have to sort of know that you're going to be asking certain questions, backing it up with a bit of evidence, and then supporting it with a real idea. A theory.

She pointed out that contrary to science in general—or the art of gaining knowledge generally—in biology one should be asking a certain kind of question dealing with a particular set of content. In addition, in the process of answering these questions, evidence and theoretical support are necessary foundations upon which to draw. In discussing the theoretical support (“a real idea” or “a theory”) one can assume she is referring to the canon of established scientific understandings. This process then, of gaining knowledge in biology, establishing evidence as a backing, and drawing upon theoretical support is what happens in biology class, in science education; in other words, the “what” to the “how” of science.

Near the end of the earlier classroom discussion, when discussing evidence and reasoning, Ms. Stoneham made the transition from process to identity by phrasing her question to the class as “What’s the goal of a scientist?” By making this move from a process to a type of person, she was also moving to identifying who participates in biology, that is, scientists. At the end of the week of that first classroom exchange, the students engaged in the Drawing Science in Action
activity (the results of which are described below). The biology classes which met
during the C-block’s time slot were also visited by a working scientist from a
nearby natural history museum who spoke to them mainly about the threats upon
science education by groups and individuals who would cast doubt on the process
of evolution, as well as briefly about his work studying the determination of sex
chromosomes in leopard geckos. At the beginning of the class period after these
two events, Ms. Stoneham led a discussion around students’ impressions:

Teacher: So a lot of you in your pictures and things like that never
really put yourself in the picture, you didn’t think of yourself
as scientists. I found that interesting. You don’t think that
like in here you’re scientists?
Margarid: When we’re doing labs.
Teacher: When you do labs. So, in your mind you’re a scientist only
when you’re doing a lab.
Male Student: Yes.
Juana: No.
Teacher: No.
Juana: I feel like when we’re doing homework and learning new
things.
Teacher: So also when you’re doing homework and learning things,
you’re a scientist.
Amanda: I really don’t think I’m a scientist.
Teacher: You don’t think you’re a scientist [unknown]. So, people,
he [referring to the visiting scientist] brought up some really
interesting things, I thought that, uh, as a scientist they look
at evidence and use evidence to make statements. And in
your own life, do you ever look at things and make a
statement?
Eduardo: Yeah.
Teacher: Yeah. So are you really a scientist then?
Eduardo: In a way.
Teacher: I mean, even on a simple thing, everybody listened to the
weather report today, right? Or you open your window
sometimes. So what did you do with that information? Do
you decide what to wear as a result? So you had to, kind of, do what? You had to think about it, make an assumption, and prepare yourself based on prior knowledge. This is really what a scientist does. They take some evidence, they state some patterns, or some observations, and then they draw and make conclusions. And you guys heard the weather saying it was going to be 70, hopefully, today, therefore you knew that, you know, I mean, I’ve seen a number of students out in the hall today wearing shorts!

First of all, Ms. Stoneham in this second exchange reinforced the idea that the knowledge gained in science education should have an impact on students’ identities and sense of how they conduct themselves in the world. More specifically, she was pushing for students to think of themselves as “scientists.” Secondly, a tension which I will address in discussing the students’ drawings of “science in action” is clearly articulated in this exchange. Margarid points that she feels like she is a scientist when “doing labs.” Juana expanded the notion of being a scientist to “doing homework” and “learning new things,” in recognition of Ms. Stoneham’s broad definition of science which she shared with the class the week before. It was in response to Amanda’s expression of rejection, “I really don’t think I’m a scientist,” that Ms. Stoneham brought the discussion back to the “subset” of skills learned in biology, working with evidence, finding patterns, and making (or in this case, acting on) a claim. She brought in a tangible example to illustrate her case, deciding what to wear based on the weather, as if to say that even in everyday life one acts as a scientist.
Understanding the field from Ms. Stoneham’s perspective, that is, science as “gaining knowledge” and science education as the content and subset of skills including working with evidence, identifying patterns, and drawing upon established theories and ideas to make and act on claims, the question arises how she orchestrates these pieces in her work as a teacher. In the next section I will describe the variety of roles of the teacher that Ms. Stoneham described and some of the strategies she draws upon in those roles.

**Acting in the Field: Ms. Stoneham’s Roles of the Teacher**

The field may be defined in terms of the roles that people play as well, in the terminology of figured worlds, the positionality agents are afforded as well as the spaces of authoring they carve out to shape the field. This section will describe the roles of the teacher as described by Ms. Stoneham (see Figure 6), in relation to how she teaches science education. I asked the question directly of her when she used the phrase “serving my clientele” in reference to teaching her students.

![Roles of the Teacher](image)

**Figure 4.2.** Roles of the teacher as described by Ms. Stoneham.
Ms. Stoneham defines seven roles for herself as a teacher (see Figure 4.2), which fell into three broad categories: Pedagogical Roles, Professional Roles, and Management Roles. Ms. Stoneham defined Serving Clientele and Responding to Test Pressure as pedagogically-related roles. She named being a Member of the Department as a professional role which had an impact on her pedagogical practice. Lastly, Ms. Stoneham described several management-type roles, including Administrative Jobs, Classroom Materials, Technology Problem-Solvers, and Student/Behavioral Issues. I will discuss each category in further detail.

In terms of the Pedagogical Roles, Ms. Stoneham listed two strategically-oriented roles of the teacher, Serving Clientele and Responding to Test Pressure. When describing what “Serving Clientele” refers to, Ms. Stoneham stated, “When I say clientele you have to know each and every one of your classes as a group. 'Cause each class you have has different needs.” But it is not just knowing the class as a group, but also understanding the range of individuals within each class. As Ms. Stoneham describes,

Who am I servicing? How many ELLs [English Language Learners], how many IEPs [students with disabilities served by Individualized Education Plans], how many language learners, or what, what is my individual make-up and how do I have to present my information to hit all of those students.

Serving the clientele in the class involves being aware of and addressing the individual needs of students based on language and ability, and recognizing how to best provide for the class as a whole through the presentation of information “to
hit all of those students.” In Serving Clientele, Ms. Stoneham connected to the
notion of craft knowledge mentioned earlier in this chapter.

Responding to Test Pressure is related to Serving Clientele, in that it
provides an impetus to examine what and how biology is being taught and match
her presentation style with her students’ learning styles. Ms. Stoneham related,
“So the MCAS is a good thing, sort of…. I think. ‘Cause it’s really making you
think, look hardcore at your curriculum, and how you’re presenting information.”
This examination of curriculum and matching of presentation and learning styles,
according to Ms. Stoneham, is geared towards success:

Researcher: You’ve used that word a couple of times, success. Can
you describe it for me?
Teacher: An increase in successes measured by how many students
pass or get needs improvement, basically reduce our ratio of
how many fail, and why are they failing, and what are we
doing to get them to be able to getting needs improvement.
That’s basically it, and at the end of the year, we are measured
by the number of students that fail the [high-stakes test].
Researcher: Not by the number who’ve passed?
Teacher: No.
Researcher: And what’s the significance of that?
Teacher: They feel that if, the more we have, the larger number of
failures, the worse job you did. What are we going to change
next year so that number goes down. How are we adjusting
our curriculum to decrease that number. Support
mechanisms, classroom mechanisms, have you assessed your
curriculum, where are they not doing well in as far as looking
at the [high-stakes test] and doing an extensive data analysis.
Are they not doing well on evolution, are they not doing well
on cells, and readjusting our curriculum for the next year to
make sure that we spend more time on that area, or did assess
how did you present that material. Obviously you want to
increase, use it if it was successful, but if you’re getting less
success, then change your curriculum strategy on how you present the information, so that subject has a better success rate next year. So it’s all about how we’re going to address our curriculum.... One of the biggest things we’ve noticed is that our students aren’t answering the open response questions. And that’s what we feel that getting them to think about claims-evidence-reasoning when they’re writing, they’ll do, it’s shown, at least all the studies show that they have an increase in writing skills. And that’s why we’re doing more writing in class. They experience it more on a daily basis, they won’t be so shy about it. And we’ll be making them better writers.

Success is not framed in the positive sense, in terms of celebrating achievement, but instead in terms of limiting failure. Ms. Stoneham ties her own job performance to these terms, as she stated that “the larger number of failures, the worse job you did.” She also touched on the subset of skills she identified as being crucial in gaining knowledge in biology, “claims-evidence-reasoning,” but positioned these skills within the framework of improving student writing on the test and increasing chances of students not failing. She noted that she incorporates these features into her class on a regularly to improve their confidence, “[a]nd we’ll be making them better writers.”

Ms. Stoneham also exhibited a nuanced stance on the Test Pressure role. Despite the benefits of pushing her to “look hardcore” at what and how she teaches, she did identify some problems with the high stakes exam. “At the same time,” she related, “I hate to be judged on a test.” Ms. Stoneham also recognizes
the pressures of high stakes tests, for her and her students, and suggested that she is working to mitigate some of those pressures:

I’m trying to get away from the [high stakes test] pressure because the past four years I’ve been here it’s been live or die the [high stakes test]. Everything in your classroom is meant to be geared toward a test... and getting your kids, and it still is to a certain extent, but um... I’m personally trying to get away from that because I think that atmosphere is making the students more tense and not like science because all they see it as is that’s they’re taking science, is to pass their [high-stakes test]. That’s all it’s about, and it’s kind of getting what, there’s huge pressure to have success!

Related to Responding to Test Pressure specifically and her Pedagogical Roles more generally Ms. Stoneham identified serving as a Member of the Department as one of her roles. As a member of the Biology Department within the Science Area at Cotstead High School, she has a number of specific responsibilities:

We now have a lot more department requirements. Making sure our objectives are visible so that students know what they are learning, the department is also, for biology, is really, trying to push claims-evidence-reasoning in writing.

As a member of her department, she ensures that her objectives are posted on the wall of her classroom. She introduces daily objectives at the beginning of each class session, usually in a PowerPoint slide, and then also had the district-wide “curriculum map” on laminated green paper hanging on the wall, referring to it at the beginning and end of each unit. The curriculum map consisted of a bullet-point outline of the top level grade-level state standards (see Figure 4.3). She also provided another source of impetus for utilizing the claims-evidence-reasoning
framework in writing, not just to improve students’ writing skills for success on the high-stakes test, but also because this is a priority set by the department. Ms. Stoneham noted that some of the departmental requirements are due at least in part to external factors, such as turn-overs in administration:

They’re keeping us really busy, this year is a very busy year, because we have all new administration, we have a new principal, the interim superintendent, the director of biology is new, this is her second year, so she is really grabbing hold. So there’s a lot of external pressure.

Figure 4.3. Ms. Stoneham’s wall with three levels of objectives: yearly (green laminated paper), weekly, and daily.

Moving from the external pressures as Member of the Department, Ms. Stoneham identified a number of managerial-related roles which supported her Pedagogical Roles less directly than her Professional Role. She named
Administrative Jobs such as keeping attendance, marking grades, and communicating with parents. She also described managing Classroom Materials, such as ensuring that there are sufficient supplies such as pencils, paper and copies of worksheets, as well as reserving technologies such as projectors and computers in an appropriate and timely manner. Related to the classroom materials, she also named being a Technology Problem-Solver as one of her roles, troubleshooting problems with her in-class desktop computer and her SmartBoard and working with the school’s technology staff to fix problems she herself could not address alone. Lastly, Ms. Stoneham pointed out the obvious management point, that she had to maintain the attention of teenagers for a class period: “Managing 15-20 individuals for 60 minutes. Meeting all their needs for 60 minutes, each of their needs for 60 minutes.”

Even though Ms. Stoneham was able to delineate these seven different roles, this does not mean she saw herself filling only one role at a time. “We do a lot of different things, we’re multitaskers,” she said. “Key multitaskers.” As a teacher, she multitasks and juggles roles in order to learn how her students learn and help them efficiently and effectively participate in science, assisting them in order to pass the high stakes exam and learn about themselves and their bodies to promote health and seeking help when needed. Her explanations of science, science education, and her roles in these endeavors were in-depth and detailed. In
the next section, I turn to the perspectives of students and explore how they defined the field.

**Knowing in the Field and the Role of the Teacher: Introducing the Student Perspective**

As I turn to the student perspective, I should point out that direct student responses through interviews were not as in-depth and detailed as Ms. Stoneham’s. This is neither surprising nor problematic, but the information they did provide was rich and thoughtful in its own way. At times, particularly when describing the larger field of science itself, they were providing me with close interpretations of the classroom discourse. At other times, they presented counterpoints to some of the points provided to me by Ms. Stoneham, in particular in relation to the role of the teacher in the science classroom and the nature of science education.

In interviews, Ms. Stoneham very clearly placed an emphasis on strategic practice to her role as a teacher. This emphasis was especially clear in terms of her description of “serving clientele,” matching her content delivery with particular characteristics of individuals in her class. One role missing from Ms. Stoneham’s description was brought in by a number of students, the role of the teacher as a source of knowledge and answers to questions.

The students noted a material instantiation of this role, as Ms. Stoneham reserved an area of her wall to collect student questions over the course of the week, referred to by the teacher and students as “The Parking Lot.” Students could
put sticky notes with questions about the science content of the week, or ask general science questions. Debra, a student from Brazil, described sharing knowledge as a central role of a teacher:

Debra: I think that she thinks that evolution is like the big idea kind of too. Since she talks a lot about it. And she’s like it’s her main goal. Even though we talk about DNA, like, it’s like, it’s her job to teach us about like all those stuff. She really like, when she was talking about evolution, she really got into it. And I like how she likes to help us too, since she does the question thing. That board. Like if we have a question, we just...

Debra: Yeah. She likes to share her knowledge too. She’s not a selfish teacher.
Researcher: Mm hmm.
Debra: ‘Cause I had a teacher, not last year, but like in Brazil, if you asked them a question, like this teacher, he wouldn’t answer. He was like, well you have to find out, he kept his knowledge for himself, even though he was a teacher.

Debra described evolution as a central principle in biology and connected the concept of DNA to it, noting how Ms. Stoneham does so as well. She indicated that making these connections clear is “her job.” In addition, in relation to The Parking Lot, Debra remarks that Ms. Stoneham is “not a selfish teacher” and “likes to share her knowledge.” She positions this attitude towards sharing knowledge against her teacher in Brazil who refused to answer questions, attributing this refusal to a sense that “he kept his knowledge for himself, even though he was a teacher” (emphasis added). Teachers by their very purpose, according to Debra, share their knowledge with their students. Yet Debra does not position this role in
strategic terms as Ms. Stoneham does, but instead she sees a teacher as a source of knowledge and understanding.

Gabriel similarly noted The Parking Lot, but described it not only as advantageous for students but beneficial for Ms. Stoneham as well:

Gabriel: Fridays we’ll ask questions, I don’t know if you’ve seen them on like this wall. On the outside we’ll post sticky notes and stuff. And we’ll ask questions about stuff we want to know that has to pertain to science. And sometimes she might not know the answer, so maybe she’ll go and look it up. And if she does know, I feel like, maybe she doesn’t learn it from us, per se, but she’ll remember it because of us, because we asked the question about it.

Researcher: So you think it’s important for her to get questions from you guys.

Gabriel: Yeah, just... like review, I guess, for her. Just to remember other stuff that we’re not, maybe discussing in the class during that time period. Like right now we’re talking about the DNA, and replication, and maybe somebody will ask her something about animals or something. It will be kind of like her review.

In this exchange, Gabriel positioned this as not only useful and beneficial for the students, but for the continued professional development of Ms. Stoneham.

Gabriel reasons that students may ask biology-related questions not directly connected to the science content at hand in the classroom. These questions can help Ms. Stoneham brush up on a range of science topics, phrasing it in classroom terms as Gabriel did, “It will be kind of like her review.” It should be noted that from Gabriel’s perspective, as a source of knowledge, Ms. Stoneham already knows the answers. It’s just that she may need to review to be reminded of the answer.
Juana also brought in the notion of teacher as a source of knowledge and as a resource for questions, but from a personal perspective:

Juana: I'll learn about, like, I don’t know, helping skin and stuff, and I’ll ask my teacher, oh, what’s in lemon that makes your skin exfoliate? And I don’t know she said, it like takes skin, like the old cells, and like puts in new cells, and then that kind of like, um, attached to DNA, and making new cells, and I found that really interesting.

Researcher: Did you learn about, you didn’t learn about lemons and skin in here, you learned about it somewhere else, and asked?

Juana: No! Yeah, and it came together.

Juana raised a specific example of learning from a source outside the classroom that lemon can aid in skin exfoliation. She then asked Ms. Stoneham for more information, particularly how the process works, “what’s in lemon that makes your skin exfoliate?” Receiving a more in-depth explanation from her teacher, she was able to connect a topic of interest to her—and her health—from an outside source to the science in the classroom. Juana was then able to connect the explanation, even at a surface level, to the topic being discussed in the classroom, namely DNA. “[I]t came together,” she remarked, yet it couldn’t have if Ms. Stoneham did not serve as a resource for answering questions and a source of knowledge and information.

Moving to a strategic perspective, Ms. Stoneham also did not mention a pedagogical strategy that seems to be both useful and favored by a number of her students, that of the use of metaphor and simile in her teaching. Gabriel brings up this pedagogical strategy in this conversation I had with him:
Gabriel: I’d say it’s how she connects them, how she connects what we’re learning to other things we already, to make it easier on us to learn.

Researcher: Can you give me an example of that?
Gabriel: Um...
Researcher: About connecting to something you already know.
Gabriel: Yeah, we’re learning about the, like the splitting, like DNA, she connects it to a zipper, like how it pulls apart, from one end to the other.

Gabriel pointed out that the fact that Ms. Stoneham connected the largely unseen process of DNA splitting to the zipper, an everyday object that students recognize and utilize on a regular basis. Gabriel noted that such associations “…make it easier on us to learn.”

An example of her use of metaphor and simile can also be found in classroom discourse:

Teacher: Just another real quick thing, just take a real quick second and look at everybody’s shoes in this room.
Leah: I love my shoes.
Henry: My favorite shoes.
Gabriel: Mine don’t have shoe laces.
Teacher: OK, look at everyone’s shoes, just for a quick second. Alright, so just a silly little side note. But, do most of the shoes have pretty much the same shape?
Gabriel: Yeah.
Teacher: Why do they have the same shape?
Gabriel: Most people’s people’s feet are the same shape.
Teacher: Because everyone’s feet. So their shape is related to what.
Gabriel: Our feet shape.
Beryl: Their function.
Teacher: Their function. So shoes are related to function, their shape is related to function, we can take that whole concept across the board. We have different shoes on us, right? We got some boots, work boots, some things that have ties, some things that don’t have ties, we have open heels, closed heels, high
shoes, low shoes, laces, no laces. Alright, do they all, because of their construction, as a result of those, do they all do something slightly different for your feet?

{Several students respond at once.}
Teacher: Yes, so if I talk about organic molecules, I’ve got carbohydrates, I’ve got lipids, I’ve got proteins, I’ve got nucleic acids. They’re all compounds, right? Just like your shoes are all shoes. They’re all slightly different. Just like your shoes. So they all perform a slightly different job. Make sense? OK? So that’s what we’re going to think about a little bit, is when we talk about our molecules, we’re talking about chemicals, but they all have slightly different shapes, therefore they all have slightly different jobs.

In this example from the classroom, Ms. Stoneham used the idea of structure and function, specifically with the organic molecules that make up DNA and RNA, as the target concept she wanted to describe to her students. The diversity of shoes in the classroom and the different shapes and uses of these shoes within particular constraints served as the model by which she explained the concept of the organic molecules that make up DNA and RNA.

Students viewed the teacher as primarily a source of knowledge—and expected her to share her knowledge—and a resource for answering their questions. The students saw this as helpful to themselves, their lives outside the classroom, and even to the continuing professional development of the teacher herself. Seeing the role of the teacher in this way was not described by Ms. Stoneham, who described the role of the teacher in more strategic terms. One student was also able to highlight a particular strategy found to be helpful that Ms. Stoneham did not herself describe, that of the use of metaphor and simile in her
teaching practice. As a representative fixture within the field of science education, Ms. Stoneham plays an important role in the act of learning when the field is described by the students themselves. In the next section, I will present a description of science education which stood distinct from Ms. Stoneham’s description.

**Practice and Learning: Students and Science Education**

In addition to some areas of connection and disconnect between students and the teacher on the role of the teacher herself, there were also some disconnect on the nature of education and learning in science. Ms. Stoneham was keen to position “science education” as the knowledge being gained, the content that one engages with in the larger project of science, of gaining knowledge. While not as detailed as Ms. Stoneham’s position, one interview with Gabriel stuck out as a necessary and interesting counterpoint to the concept of learning as “gain.”

The conversation began when I tried to challenge Gabriel on his assertion—following Ms. Stoneham’s—that “…the word science can relate to everything. Other classes.” I asked him if he takes a music class, and he responded that he takes guitar lessons. I asked him if that was science, to which he replied:

**Gabriel:** I mean, yeah, cause like it’s like, like I said, science is like learning, and with, uh, well with guitar, specifically, you have to learn like all the notes, and how, what they sound like, so that’s kind of like observing, except just listening. So that kind of has, what my definition of science. And then, just, I mean with music, like learning an instrument is kind of different, but I mean... it’s still kind of, how can I explain it?
I'm trying to think of the word, but, I mean yeah, I do think it's kind of science.

Researcher: So it's kind of science. And then, how is it not?

Gabriel: Well, I mean, 'cause it's also like a hobby. I mean, music. Because I'm I'm big into music, so I love to listen to music, and I love to just like listen to different types of music and see what they all sound like. And what they talk about, and what’s the meaning behind songs. I mean, science can be a hobby, too, but I feel like with maybe learning an instrument like I am, there’s a lot of practice involved. And with science, with science class, I don’t really think there’s like a lot of practice, I think it's just like learning.

Researcher: Hmm. What do you mean by that?

Gabriel: Like, um...

Researcher: So what’s the difference between just learning and practice?

Gabriel: Well, I mean, practice is, I feel like you kind of have to keep having to do something just to understand it, or get it, kind of be able to do it without thinking. So like, riding a bike, for example, is kind of like the same thing. Like you kind of just need to keep doing until you kind of, it’s kind of like second nature.

Gabriel positioned music and learning to play guitar as “kind of” science, as there were skills involved that were related to science, such as observation. Yet he also brought in that guitar for him is a “hobby,” which he directly connected to a sense of passion, and his interest in delving into “the meaning behind songs.”

While he admitted that “science can be a hobby, too,” he made a clear distinction between practice, which he attributed to guitar, and learning, which he attributed to science. For Gabriel, practice is when you “...have to keep having to do something just to understand it, or get it, kind of be able to do it without thinking.” With practice, there is a sense of repetition, but through repetition one
understands it and the practice is embodied by the practitioner, as Gabriel called it, “...kind of like second nature.”

Gabriel described learning differently:

You can be told something, and maybe you, like, you don’t learn it right then, but then, kind of like, going in depth into it, and figuring out why it’s true or som-, or like... like going into, let’s say, the water cycle. Maybe you don’t understand why that’s true, but somebody tells you, the science teacher, she tells you that it’s true. And then you go in-depth into it, maybe you’ll do a lab and evaporate water and see it go away. And so, you’ll know that’s true by seeing it, looking at it, with your own two eyes. And then, I think... I don’t, I hadn’t done this lab, but I’ve heard they’ve done clouds like, they made clouds in a little container-like thing. I haven’t done that, but, I mean, that’s proof right there. So I mean that’s kind of like being told something and then proving to yourself that it’s true.

For Gabriel, learning is primarily a process of being told something is true, receiving information, and then testing that truth through experience. He brings in the example of the water cycle and how a teacher can tell a learner that the water cycle is a process in nature. He then describes a lab activity that can be used to see the process happening. It is this process of receiving information and seeing this information first-hand “with your own two eyes” that Gabriel refers to as learning.

In addition to making procedural distinctions between practice and learning, Gabriel also assigns different goals to the two processes:

I feel like the end goal is similar, but for practice, you kind of, your end goal is to get better, and kind of like, with practice it’s harder, because you have, maybe you have your own goal, like let’s say I want to like play this type of music, but it’s really hard, because let’s
say it’s really fast. So I want to practice at faster playing. But with learning, I feel like, you want to learn more. It’s not really getting better at anything, but you’re learning more, so you’re getting more information.

With practice, according to Gabriel, “you have your own goal.” Related to his connecting learning guitar with his passion and exploring meanings behind songs, Gabriel is highlighting a sense of self-determination with practice. Relatedly, the person who practices, according to Gabriel, is also getting better at doing something. But with learning, in Gabriel’s schema, the learner is “...not really getting better at anything, but you’re learning more, so you’re getting more information.” This connects with Ms. Stoneham’s sense of “gain,” but is not held by Gabriel with the same esteem as practice.

With respect to the differences between the savoir- and connaître-types of knowledge explored above, it would seem at first glance to mirror Gabriel’s distinction between learning and practice respectively. However, Ms. Stoneham discusses the puzzle activity of the connaître-type not quite as embodied practice, where students get better at accomplishing it, but instead positions the activity more as discovery. Similarly, in highlighting the need for review, which can be seen as the cognitive analogue to embodied practice, Ms. Stoneham again does not, as Gabriel would seem to want her to if she was to take the perspective of practice, frame the review in terms of “getting better.” Instead, she positions the need for review in a way that calls attention to the gain and loss of knowledge in
the brain, consistent with Gabriel’s sense of learning. Therefore, both Ms. Stoneham’s *savoir*-type and *connaître*-type of knowledge can be seen to align more strongly with Gabriel’s sense of *learning* rather than *practice*. That *savoir* aligns with *learning* is expected, although that *connaître* does is more surprising.

Gabriel described a complex relationship between learning and practice, where learning was “getting more” and practice was “getting better.” This stood in contrast to Ms. Stoneham’s sense of science as “gaining knowledge.” These two positions on how learning is accomplished within the field of science education are notably distinct. This distinction is important to note as the move is made from the field to meaning in the next chapter, as the practices described here touch upon meanings, values, and goals. From learning science to science itself, I now move from understanding the student perspective of science education to how the students describe the broader field of science.

**Students and Science**

Two activities provided frames for understanding how students conceptualize science: the Stories of Science-in-Action pile sort activity and the Drawing Science activity. I will provide an overview of the results and analysis from these two activities in this section as a way to fill out the field of science education and the science classroom.

**Drawing Science.** Students were asked to draw a picture of what “doing science” looks like, and then to fill out a reflection sheet afterwards. Students were
asked to engage in this activity twice, once at the beginning of Phase II of the research and once at the end of Phase III. For the purposes of charting a conceptual picture of the domain of science as understood by the students, only the first enactment of the activity is considered in this section. The second enactment is discussed in the next chapter when considering the idea of science and meaning more directly as the idea of what science means to these students was highlighted repeatedly in classroom discourse, practice, and activity.

By the time that the students engaged in this activity, the teacher had already discussed the idea of science as gaining knowledge with them. There was some general resistance to this activity. First of all, several students complained that they did not know how to draw well. Gabriel forcefully resisted the activity and complained quite vocally. The teacher decided to assign other work for him to do outside of the classroom so that his attitude did not influence the rest of the class as Ms. Stoneham noted that Gabriel serves as an intellectual leader in the class and other students often take their cues from him. It should also be noted that Ms. Stoneham decided to have all of her classes engage in this activity, although their drawings were not collected nor are they analyzed here. She had her other classes complete this activity before the C block class. Based on her experiences in her other classes she was enthusiastic to run this activity.

The drawings revealed a number of characteristics that students attributed to science, such as where science is done; what equipment, knowledge, and concepts
are involved; who does science; and how science is done. Generally, students placed the doing of science in a laboratory, in nature and the outdoors, or in a space without a particular context. They also drew laboratory accoutrements such as test tubes, beakers, microscopes, and lab benches; natural features such as clouds and trees; and concepts such as XX-XY representing sex chromosomes, diagrams of cells, and representations of the double-helix structure of DNA. Although many of the students drew stick figures, some of the people who were engaging in science were drawn with lab coats and safety goggles, although other people were drawn in as subjects of science. Holistically, the student pictures of doing science fell into four general categories: Gaining Knowledge; Science as Collection; Science as Activity; and Science as Nature.

**Gaining Knowledge.** Drawings which tended to fall in the Gaining Knowledge category (Figure 4.4) were clearly interpretations of Ms. Stoneham’s description of science. Whereas Ms. Stoneham tended to describe the gaining of knowledge as an active process, the students interpreted the process as passive. Things were drawn around heads or brains with arrows indicating that they were being put inside. The things which represented “knowledge” tended to involve a “typical” sense of science content (illustrations of viruses, cells, DNA strands, etc.), although at times included a broader and more general sense of “knowledge” to include other subject areas as well. One student drew a picture which depicted
the Earth floating in space connected with arrows to a disembodied brain also floating in space.

![Representative drawings in the Gaining Knowledge category.](image)

**Figure 4.4.** Representative drawings in the Gaining Knowledge category.

**Science as Collection.** The second group, Science as Collection (Figure 9), tended to represent doing science as collections of ideas, concepts, and paraphernalia. These collections did not tend to be tied to a particular place, nor did they typically involve human activity (with one exception, in the drawing in Figure 4.5 on the right with a person holding what appears to be a light or microscope). One student drew science as a book to depict knowledge across a range of subject areas collected in one place. The knowledge collected in this book included topics such as biology and the other school sciences topics (e.g., math, English, and business), and even child care. This student’s representation is a different interpretation of Ms. Stoneham’s general description of science as representing all subject areas. Other students drew other objects and ideas, such as plants, test tubes, DNA strands, and the recycling symbol. It is also interesting to note that the lab bench depicted in the middle drawing of Figure 9—with a
black top and a brown wooden bottom—reflects the form of the lab benches in the classroom.

Figure 4.5. Representative drawings in the Science as Collection category.

Science as Activity. Drawings of Science as Activity (Figure 4.6) were typically tied to particular places and included people in these places. Although the middle picture in Figure 10 was not tied to a particular place, it was included in this category because of the strong presence of the person in the drawing. The places were either outdoors in nature or in a laboratory setting (or both, as in the left drawing in Figure 10). The laboratory-like settings reflected fairly closely the classroom’s lab area, including the black-and-brown lab benches. The people in the drawings were usually doing things, such as investigating and examining or working with test tubes. While the left drawing in Figure 10 tied back to Ms. Stoneham’s knowledge statement, the drawings in this category were active rather than passive, were usually tied to a place or person, and any paraphernalia or props were tied together and oriented to doing a particular task unlike the drawings in the Science as Collection category.
Science as Nature. The drawings in the Science as Nature category (Figure 4.7) ranged from the general to the specific. These drawings tended to depict “doing science” as nature itself, with scenes of grass, trees, animals, water, and suns. They also brought in specific content from the curricular unit being studied at the time, and tended to depict people with particular sex chromosomes (XX and XY). These drawings tended to reflect the notion that doing science is connected to nature, and that “science is everywhere,” a theme which was often invoked in interviews as well as classroom discourse.
The “science is everywhere” theme was a topic of discussion in the small groups looking over each other’s drawings. I sat down to observe one group consisting of Margarid, Henry, and Rosa. While the students were categorizing the drawings and answering some reflection questions, Margarid asked me a question which invoked a deeper discussion:

Margarid: Isn’t everything, isn’t everything, like, have to deal with science? Like anything has to do with science in some way.
Researcher: Mm hmm. Mm hmm.
Margarid: Like, about animals.
Researcher: OK.
Margarid: And like... the air [laughter].
Researcher: Mm hmm.
Margarid: Just like everything has to do with science!
Researcher: OK. So, but based on these pictures.... Well, OK, I see your.... Well, you’re asking like a general question, right?
Margarid: Yeah.
Researcher: Yeah. So, does a painting of a fish [pointing to the fish tank on a nearby counter] have to do with science?
Margarid: A painting?
Researcher: Yeah. I’m asking...
{two students talking at once}
Henry: It could be the actual, looking at the actual fish...
Margarid: ...Looking at the actual fish, and it’s a fish, and the fish is an organism, and the characteristics of the organism we’re looking at science.
Researcher: OK, so... so, when you sit down in history class, is that science?
Margarid: No.
Researcher: No? How come?
Margarid: Yeah, it kind of is...
Henry: It’s science history!
Rosa: {unknown}. It’s not really science, they’re not talking about science.
Henry: Well, it could involve it, it’s just not mentioning it, because that’s not what the subject’s about, so they could involve it.
This discussion is in part in reaction to the classroom discourse several days beforehand when Ms. Stoneham introduced science as “gaining knowledge” and asserted that there is a “science of history.” When asked about a painting of a fish—meant as an artistic representation—Margarid and Henry both pulled it under the umbrella of science. This move not only brought artistic representations and interpretation into the domain of science, but nature as well with Margarid’s comment that “…it’s a fish, and the fish is an organism, and the characteristics of the organism we’re looking at science.” They also dealt with the concept of subject matter when I asked them if history class was science. Rosa was willing to distinguish history from science, while Margarid was more tentative, and Henry was ready to classify history class as science because history “could involve” science. These categories of drawings and discourse such as the dialogue above point to some difficulty by students in developing firm categories in defining what is and what is not “science.” The classification process was in part problematized by Ms. Stoneham’s explicit definition of science as gaining knowledge and insistence that science applies to any pursuit. In the interest of disclosure, I confided in the three students that their questions and concerns were being debated by scientists and philosophers, and that I did not have a definitive answer for them.

Who does science was also a topic of discussion, as Ms. Stoneham noted, as discussed above, that none of her students placed themselves in their pictures. In
discussing the visit by the scientist from the nearby natural history museum, Ms. Stoneham asked her students to reflect on the people they drew in their pictures and the scientist as a person:

Teacher: So, your impression of a scientist, then, does it change at all, are you adding to it at all? Because remember we did our drawings about what does it mean to do science.
Gabriel: Well, he seemed pretty normal to me.
Teacher: Isn’t that nice, that science people are NORmal. Scientists are normal.
Beryl: I wanted him to be like wearing a lab coat.
Teacher: That’s a very interesting point, that you wanted him to wear a lab coat. And a lot of you in your pictures, when you said doing science had lab coats on.
Beryl: Oh, when you said we’re having a speaker, I said, oh, he’s going to be wearing a lab coat.
Margarid: I thought it was going to be more chemistry stuff.
Teacher: You thought it was going to be chemistry stuff.

Ms. Stoneham emphasized a few themes in this short exchange. First, she picked up on Gabriel’s observation that the visitor seemed normal. “Isn’t that nice,” she responded, “that science people are NORmal,” with the emphasis on the normal.

She also brought attention to Beryl’s prediction that the visitor would be wearing a lab coat, by pointing out that many of the students drew lab coats in their pictures. Upon examination of the students’ drawings, however, this did not prove to be the case; of those who drew people with clothing at that level of detail (many students drew stick figures, even if the rest of their drawing was fairly detailed) only one student drew a person wearing a lab coat. The empirical evidence, however, is moot, and this was not introduced as a way to discredit Ms. Stoneham. Instead, it
was introduced to highlight the deeply ingrained categories and assumptions that even the teacher holds of her students’ representations of science. Lastly, Ms. Stoneham highlighted Margarid’s comment that she expected to see “chemistry stuff.” Ms. Stoneham concluded the conversation with the following:

So, those are the things that you’re conjuring up when you think science. Kind of like a lot of you in your pictures you did lab stuff. You wear a lab coat. So as a scientist, you wear a certain set of clothes, and you work with a certain set of equipment?

Ms. Stoneham reinforced those categories with “So as a scientist, you wear a certain set of clothes, and you work with a certain set of equipment?” While she reinforced these categories in order to call them to question and cast doubt on their certainty, Margarid, with the final word, was in turn uncertain: “Kinda,” she replied. In her uncertainty, it seemed as if these categories were not easily displaced. These categories form a large part of the conventional and tacit field of the science curriculum and classroom, providing opportunities and barriers within the context of a figured world on the make. I will return to these categories in the next chapter when discussing the ways that students’ perspectives of the field changed, often in unexpected ways.

Understanding the Relationships between Stories of Science-in-Action. I also asked the students in the class to participate in a pile sort activity, which allows for the visualization of the relationships between different aspects of science. Students were asked to place different stories or vignettes describing
people doing activities related to science into any number of related piles. I then interviewed each one individually in turn and asked them why they placed each of the vignettes into the particular piles. The results of the pile sort activity were entered into ANTHROPAC (Borgatti, 1992), which provided the aggregate proximity matrix provided in Appendix J. This matrix was then imported into UCINet (Borgatti et al., 2002) and a non-metric multidimensional scaling (MDS) analysis was conducted on two dimensions. The results of this analysis can be seen in Figure 4.8. Stress, a measure of goodness of fit, was calculated to be 0.096 in 14 trials. As the stress value for the MDS analysis was less than 0.1, it is within acceptable limits (Borgatti, 1997).

By examining the diagram generated through the MDS analysis and comparing the diagram with the interviews, I was able to interpret the scales of the two dimensions represented in the diagram. The x (left-right) dimension exhibits a continuum identified by the students between “People” on the left and “Things” on the right. The y (up-down) dimension exhibits a continuum between “Contributing to a Greater Community or Enterprise” along the top and “Individual Enjoyment” along the bottom.

A cluster optimization analysis was conducted to determine the optimal number of clusters that could be found in the MDS analysis. According to measures of both fit and r-square values, four clusters was calculated to be the optimal number of clusters with the lowest fit value (0.327) and the highest r-
square value \((0.453)\). The main four clusters are highlighted in Figure 4.8 with solid black lines.

The MDS diagram represents a composite view of how the class as a whole categorized different aspects of “doing science” based on the provided vignettes. Every student was also interviewed to provide an overview of their sorting, and although individual students’ sorts did not necessarily fit exactly the composite diagram in Figure 12, their interview statements are used to better describe the range of categories. Each cluster will be examined in turn.

“Typical” Science. The first group of vignettes discussed is the “Typical” Science cluster, which include such activities as conducting fieldwork in a salt marsh, writing an article for a science journal, setting up a bird feeder, and carrying out experiments with a particle accelerator (see Appendix I for the full vignettes). Kimberly described the group in terms of what people would think of as typical science activities, “It’s all pretty much like what people would think of biology, and like sciences and stuff.” Students also tended to relate items in this cluster in terms of contributions to the scientific community or the scientific enterprise. Gabriel termed the cluster as “…directly science,” while Beryl explained that, “[t]his group had to do with like, helping out science, like, making a journal and then, article, those were things like, helped with science.”
Figure 4.8. Multidimensional scaling analysis results with dimensional labels and identified clusters.
“Making Things” Science. The next group of vignettes is the “Making Things” Science cluster, in which students tended to place activities such as improving sticky notes, writing a computer program, making a clock, and painting a detailed landscape. Students were fairly clear in their descriptions that the vignettes represented a sense of making or improving things, rather than just contributing to science or engaging in an investigation. Matt explained that,

...this one [cluster] is like trying to make things better. So, they’re trying, I’m making them better. Like, he’s trying to make sticky notes better, and this one’s like painting, and this one’s making a clock.

Similarly, Beryl described that, “...it’s like inventing things. Like making a clock or painting.” Dylan phrased it slightly differently, in terms of experiments, but also in terms of using technology:

...all of them were doing experiments, they were experimenting on what they were trying to figure out. Like the sticky notes, they were, the person was trying to find different ways to make like the stickiness stuff. And then the particles-atoms ones, they were using something for atoms, or I don’t know, or using a machine. And, yeah, I don’t know, they were all basically all experimenting on what they wanted to do.

What is interesting is that a common thread that ran through these descriptions in contrast to the “Typical Science” cluster was that the goals of the activities were inherent in the things themselves—the end results, like improved stickiness, a painting, or an experiment—rather than in contributing to a larger community or enterprise. The students tended to attribute this contributory behavior, on the other hand, to the activities in the “Typical Science” cluster.
Science, People, and Communities. The Science, People, and Communities cluster largely represents the activities of historical research, community organizing, ethnographic research, examining a patient, and taking a walk. There was a fairly strong consensus among the students as to this group. Beryl accounted for the taking a walk vignette by positioning the social community as part of the larger natural community, stating, “...like the community is part of nature. You need a community.” In addition to the idea of studying social groups, students also highlighted the idea that some of the individuals in the vignette also wanted to assist the community as well. “These all had to do with,” related Beryl, “like a community that... or like a group of people that, like, were, she wanted to get to know or help.” Similarly, Gabriel explained that, “They are the ones that like help the people, like examining a patient, or working in a community or city. Like learning about people.”

Teaching Science. Moving from learning about and helping communities, the next cluster is about teaching. The vignette which described the activity of teaching biology is situated within its own cluster. That is, students did not consistently place the act of teaching biology in a particular pile so that it could fit into another cluster. Some students placed teaching biology as a core activity of science, as Ruby stated, “…she’s teaching like a biology class, so it’s like directly science.” Others, on the other hand, positioned teaching on the periphery, as Eduardo explained, “But it’s like they’re teaching something and, like, they’re not
really doing science....” This lack of consensus—and indeed, seemingly
diametrically opposed views—accounts for teaching biology as a cluster in and of
itself. When viewed against the dimensional scales, however, students clearly
positioned teaching as an activity which contributed to a broader community and
enterprise.

**Student Sorts and the Umbrella of Science.** It should also be noted that
students were hesitant to exclude vignettes of activities from the umbrella of
science, creating a very large umbrella indeed. Some of the activities were written
specifically to problematize the notion expressed in classroom discourse that
science could be anything and students were given explicit permission through the
instructions for the activity to exclude any of the vignettes from the definition of
science. Students, however, were tentative in doing so, although occasionally
excluded vignettes while talking through their categorization. Students were
willing to jettison the painting a landscape vignette, both in their pile sorts and in
their explanations, as Eduardo explained, “I don’t know about that one, like, it’s
just like painting. I mean, I don’t know really what it has to do the, I don’t really
see what it has to do with science.”

**Leah and Identity-Centered Sorting.** Not all students took an activity-centric
approach to the pile sort. Rather than sorting according to activities-in- process,
Leah, for example, focused primarily on identities and what their activities said
about them. In describing her reasoning behind her sort procedure, she
constructed identities and tacit narratives of being in the world for each of the people featured in the vignettes. The narratives and identities she discussed served as an interesting counterpoint to the consensus-oriented MDS analysis above.

Leah divided the vignettes into three separate groups (see Figure 4.9). The first group, Normal People/Every Day Activities, “…is just like what normal people can do.” This group consisted of community organizing, painting a landscape, making a clock, historical research, setting up a bird feeder, and taking a walk in the neighborhood. Although glossing over the expertise, skill, craft, and talent necessary for some of these activities, Leah described these activities as, “…what normal people can do in their normal day lives.” Leah pulled these activities from the domain of science, or more accurately, from the purview of scientists, and therefore describes them as “normal.”

Leah’s second group, Normal People/Scientific Activities, included the vignettes which outlined examining a patient, conducting ethnographic research, and improving sticky notes. This group, Leah noted, included, “…advanced people, who like you know, like had an education, do like scientific stuff. Like that’s their field.” These three people, according to Leah’s classification, are educated in science, “their field is science,” and are engaged in scientific activities, but aren’t defined by science. Part of her classification is that she sees their work as in a direct way benefitting people. Commenting on the improving stick notes vignette,
Figure 4.9. Leah’s categories of science by identities and activities.
she related that such work, “...might contribute to helping us, in some sort of awkward way.” She continued,

If you got to stick something on something, but you need like, give a little note. Like you know how I work at [a sports store], and we always have little sticky notes on the sides, like, to help us remember what we're doing. So we can make those even more stickier, so they won't fall off all the time.

Even if the contribution is “awkward,” as in the case of improving the sticky notes, the people are contributing nonetheless and are therefore not defined by science. I was not able to get Leah to define “awkward” for me, or to explain why improving sticky notes was awkward (“It's just awkward,” she replied to my attempt to get her to do so).

Leah's final group, Scientific People/Scientific Activities, was comprised of conducting fieldwork in a salt marsh, doing an experiment, writing a computer program, writing a scientific article, teaching biology, and breeding leopard geckos. These activities, according to Leah, “...have to do with the world,” rather than with people. “The last group is,” she continues, “it's more like outside of like, nothing that has to do with humans.” In having to do with the “world,” rather than “humans,” this group and these people are effectively separated out by Leah. These are people who are defined by science. In fact, she goes further to say, “It's just like, what scientists would, what scientists do in their spare time.” So rather than contributing anything of importance or use, no matter how “awkward,” these are activities that scientists—people who are defined by their activities in
science—engage in when there is nothing else of importance that needs to be done.

This focus on identities by Leah specifically is significant as her meanings surrounding science and the science curriculum can be traced deeply into her sense of identity. I will return to this topic in the following chapter. However, I introduce her account here as a way to highlight two ideas. First, despite a fairly strong fit with the MDS analysis, the consensus does mask some important counterpoints. While there is a general sense of the field of science education by students, there are also subtle—and not so subtle—perspectives on the field. This range of perspectives can be significant when encouraging the forging of meaning and identities through dialogue and practice, as is often the case in the classroom. Second, while meaning and identities are found within a field, they can also contribute to shaping the field.

**From Field to Meaning**

In this chapter, I put forth an outline of the field of science and science education, as well as the role that the educator plays in orchestrating learning within the field. The shape of the field was described by the teacher and her students. One would assume a description of the field that is straight-and-narrow, conventional and uncontested. The field as described by the actors in the C-block classroom, however, is surprisingly rich, textured, and at times discordant. It is by working through this discordance that Turner (1974) asserts can lead to change.
and new understandings, as Gadamer (2004) describes it, a merging of horizons of understandings.

In science education, I stress that such change and new understandings—when approached mindfully—should lead to a more humanistically-grounded science curriculum, a lived curriculum. On that pathway, however, meanings which surround the curriculum are generated and re-formed. The next chapter delves more deeply into the meanings which are found in, attributed to, and placed on the science curriculum by the teacher and her students.
CHAPTER FIVE: EXPLORING THE MEANINGS AROUND SCIENCE AND SCIENCE EDUCATION

This chapter makes the transition from reports of the fields of science and science education to an exploration of the expressions of meanings in and around these fields and focuses primarily on interviews and the activities developed to bring the ideas of meanings and identity to the foreground. This chapter primarily addresses the question, What are the meanings that arise when students are provided the structures and activities to explicitly negotiate meanings around the science curriculum? This chapter also explores the teacher’s expressions of meanings as a way to explore the negotiation of these meanings as well as to provide a fuller and more complete picture of the figured world of the science classroom.

The meanings are explored through two aspects: the private and the public. The private meanings are those influences, experiences, histories, and hopes that students and teachers bring to the science classroom and influence their engagement and practices. I will explore this sphere through a rank order activity and close one-on-one interviews. The analysis of the interviews is structured as such to highlight the personal histories and past experiences of the participants, the important relationships the participants highlight, and their anticipations for the future. Public meanings are those which emerge through activity and negotiation, whether tacit or explicit, in the context of the classroom. The activity
structures designed for this research—in terms of the framing of the activity by the teacher, the social interactions which took place during the activity, and the artifacts and reflections based on the activity—form the core of this inquiry. I will then revisit the field itself, and introduce the depictions from a second enactment of the Drawing Science activity in order to highlight the meanings around the field, as well as a change in the conceptions of the field itself. With an increasing emphasis on the practices of science in the field of science education, this understanding of the ways that the field perceived by students does or does not change while exploring meanings is an important step to understanding how to better design science curricula. As such, this exploration also addresses the question, How can teachers and curriculum developers use these processes of meaning negotiation to understand students in terms of where they are, where they have been, and how to guide them in the future?

**Influence, Value, and Meaning in the Science Classroom**

In order to understand the ways that students’ engagement in science class are influenced by factors inside and outside the classroom, the students were asked to engage in a rank order activity. This kind of activity allows for students to make judgments about the ways they are influenced in terms of their activities in the classroom and also provides insight into the values and meanings they bring to the classroom. The students were asked to order these potential influences from most influential to least influential. This data was imported into Anthropac, which
calculated a Smith’s Salience Score (Smith’s S) for each potential influence. This information can be found in Table 5.1. Each student was also interviewed individually and asked to describe and explain their reasons for ranking the influences in the ways that they did. The Smith’s S scores provided a way to consider the student rankings as a composite of the class as a whole. While individual students may have ranked these influences differently, the comparisons of Smith’s S provides an informative perspective on the class as a whole.

<table>
<thead>
<tr>
<th>Influence</th>
<th>Frequency</th>
<th>% Response</th>
<th>Mean Rank</th>
<th>Smith’s S</th>
</tr>
</thead>
<tbody>
<tr>
<td>My Parents</td>
<td>15</td>
<td>100</td>
<td>4.667</td>
<td>0.750</td>
</tr>
<tr>
<td>It’s A Required Class</td>
<td>15</td>
<td>100</td>
<td>5.067</td>
<td>0.726</td>
</tr>
<tr>
<td>My Questions</td>
<td>15</td>
<td>100</td>
<td>5.600</td>
<td>0.688</td>
</tr>
<tr>
<td>My Concerns</td>
<td>15</td>
<td>100</td>
<td>5.800</td>
<td>0.672</td>
</tr>
<tr>
<td>My Interests</td>
<td>15</td>
<td>100</td>
<td>6.667</td>
<td>0.617</td>
</tr>
<tr>
<td>My School</td>
<td>15</td>
<td>100</td>
<td>7.067</td>
<td>0.590</td>
</tr>
<tr>
<td>My Teacher</td>
<td>15</td>
<td>100</td>
<td>7.133</td>
<td>0.588</td>
</tr>
<tr>
<td>Get A Good Job</td>
<td>14</td>
<td>93</td>
<td>7.643</td>
<td>0.519</td>
</tr>
<tr>
<td>Nature and Environment</td>
<td>14</td>
<td>93</td>
<td>7.786</td>
<td>0.505</td>
</tr>
<tr>
<td>My Hopes</td>
<td>15</td>
<td>100</td>
<td>8.667</td>
<td>0.484</td>
</tr>
<tr>
<td>My Experiences</td>
<td>15</td>
<td>100</td>
<td>8.800</td>
<td>0.473</td>
</tr>
<tr>
<td>My Community</td>
<td>15</td>
<td>100</td>
<td>10.200</td>
<td>0.363</td>
</tr>
<tr>
<td>My Friends</td>
<td>15</td>
<td>100</td>
<td>10.467</td>
<td>0.363</td>
</tr>
<tr>
<td>People Around The World</td>
<td>15</td>
<td>100</td>
<td>11.400</td>
<td>0.296</td>
</tr>
<tr>
<td>My Country</td>
<td>14</td>
<td>93</td>
<td>11.857</td>
<td>0.251</td>
</tr>
</tbody>
</table>

Table 5.1. Student rankings of influences on their engagement in science class.

The influences ranked most highly by students included My Parents, It’s A Required Course, My Questions, My Concerns, and My Interests. These influences, for the most part, are immediate, close by, and carry tangible
consequences. Parents often set expectations for their children to do well in school, and it was largely the students who came from homes in which a language other than English was spoken who ranked their parents highly. For example, Juana shared, “My parents have always taught me how important it is to study. And basically, if you don’t study, like, your life won’t be the same. It causes change.” Similarly, Eduardo said about his parents, “…they want me to get a good grade, you know, and show a bit of interest in school and all the classes.” The requirement aspect of the course is one that cannot be ignored, and many students ranked this either first or second. Margarid expressed this sentiment as, “It’s a required class because that’s really why I’m taking it. Because if I had a choice, like I’m not really interested in science at all.” Of interest is the triad of students’ questions, concerns, and interests. Unlike some other influences which tended to be placed as less influential—such as My Hopes and My Experiences—questions and concerns tend to be “in the moment” attributes. Some students also attributed these to a sense of who they are. “My questions, I guess I’m curious,” explained Rosa. She went on to talk about My Concerns, linking her concerns to reports in the popular media and issues of global warming and overpopulation: “…I watch things on National Geographic and Discovery, and I see things, and I think it’s like just one degree over, and it like scared me. And then like overpopulation scares me.” While questions and concerns may arise from or have their genesis in the past or have a potential impact in the future, they tend to be triggered in
response to a particular stimulus at a time and place, and are often fulfilled in class, and do not require delayed gratification, such as with students’ hopes.

The next highest range of influences consisted of My School, My Teacher, Get a Good Job, and Nature and the Environment. These influences were seen as important, but less pressing than the above influences. For example, many students tied My School with It’s A Required Class, as Juana described it, “My school, because like, I come here, and I have to take the class.” They considered the curriculum to be set by the school, and therefore just needed to get through the class to fulfill school requirements. With My Teacher, students tended to describe her influence as one of how they engage in science class—by providing them with information to learn and activities to complete—rather than why they engage in science class. In a way, although they made it clear that they held a great deal of respect for Ms. Stoneham, the students saw the teacher as a part of the classroom environment rather than as a reason to engage in science class. “There’s a grade for participation,” related Eduardo, “so, you know.” Not all students were quite that grade focused as Eduardo. Matt linked Ms. Stoneham with motivation, “...the way she teaches me and motivates me to be successful.” Rosa similarly credited Ms. Stoneham with keeping her engaged:

Rosa: She’s kinda nice. And sometimes she gets crazy, and it’s great for paying attention.
Researcher: Oh yeah? How does she get crazy?
Rosa: Um, I don’t know, she’s just talking sometimes, and then she’ll just say something, like really loud and weird, and it gets my attention back.

Considering Get A Good Job, many students indicated that finding an appropriately rewarding career was important. In fact, Juana even tied a good job with survival, “…because without a job, I don’t have food, I don’t have anything, I can die!” Engaging in science class and a good job, however, were only loosely linked. Students were uncertain as to how science class would provide them with a particular advantage in this regard beyond a sense that science knowledge may be useful at some point, such as Eduardo, who is interested in becoming a chef, put it: “I’m not interested in science, but maybe it could help me.” Sam discussed how general success in school is a factor that may influence one’s success in life: “In order to do good in life, I got to do good in this class, I guess, in order to get a good job, and, get good grades in school.” Several students explicitly stated they were not interested in a career in science. Margarid, who placed Getting A Good Job last, was actually interested in becoming a physical therapist, a health-related career which requires a good deal of science studies. She discussed, however, how the subject of science, and how her difficulties of succeeding in science, were influencing her to follow another career path:

Margarid: I want to be a physical therapist, but then it’s, you have to like science, and I don’t like science. So I don’t really want, I’m not good at science, and you have to be good at it to keep up with all the college work and stuff, so I don’t really want to
do that anymore. So, like, I don’t know what I want to do with my life.

Researcher: Have you ever worked with a physical therapist before? Is that where you—

Margarid: No, I’ve thought that it might be fun to do. But then like when I was talking to my mom about it, and I was talking to Ms. Stoneham about it, during course selection, and she said that if you like science, and you’re good at science, then you should, if you want to you can do it. But like, I kind of realized like, I’m not really good at science, so I don’t want to go into a course that is like all about science and something that I’m not interested in, because I’m not going to have fun with it. So...

Researcher: Because it’s too hard? Or...

Margarid: It’s not like it’s too hard, I just, I’m not good with facts and stuff. It’s the same thing with history. I’m not good at learning facts about stuff. So it’s hard for me to do good on tests and study facts.

By minimizing her career interests and putting the responsibility on science,

Margarid is also making a statement about the way that science (and history) is typical taught. While she thinks she would enjoy the practice of physical therapy, she is apprehensive about the “facts and stuff” as well as succeeding on tests.

Nature and Environment was ranked next, as several students exhibited a clear concern for environmental causes. Rosa, for example, touched upon her concerns about nature, pollution, and overpopulation. She also connected her concern for nature as local as well: “I have a dirt yard, so I’m hoping that I’ll be planting plants, and I think everyone else in like my neighborhood has a dirt yard. So, it’s kind of gross.”
Next to be ranked were My Hopes and My Experiences. As noted earlier, it would seem at first that My Hopes and My Experiences should complement some of the influences which ranked higher, specifically My Questions, My Concerns, and My Interests. Hopes and experiences, however, are categories of future and past, respectively; they are not in the moment as the other three influences tend to be, and it would seem to indicate that students felt they were more greatly influenced by factors which were immediate rather than in their personal histories or in their imagined futures. At times, students such as Juana minimized their capacity to have had experiences, as she related to me, “Well, I don’t have very much experiences ‘cause I’m just fifteen, but [laughter].”

Rosa, on the other hand, who identified herself as “curious,” spoke about how an experience triggered questions and interests:

Rosa: I guess I’ve had a few experiences, that led to questions, that were kind of strange.
Researcher: Can you give me an example?
Rosa: OK, when I was like, maybe I was like 7, it doesn’t make sense that, I don’t think I was dreaming, but, I think I was outside with my friend, we were outside of my house, and it was like dark out, like the stars were out, and there was this weird thing, like, it was like light, it was... I thought it was a shooting star but it was spinning around in a circle, and I, and I thought it was something, and I asked the next day, like in the second grade and she’s like, you’re probably dreaming. [laughter] And I was like, oh, OK.

Rosa tapped into an experience that she could not explain from her childhood.

She looked to her second grade teacher who, rather than engaging Rosa in a
dialogue about the different explanations of what the light she saw could have been, minimized her question and attributed it to a dream. However, despite this lack of encouragement to seek out explanations, Rosa saw this as a trigger to a long line of questions regarding the natural and social worlds. As she related: “This is just an example, but it’s like, I want to know how things are and how they work, and how they’re strange.”

My Community and My Friends were ranked next, and People Around The World and My Country were ranked last. I will consider them here together due to the nature of these influences having to deal with social and political relationships. Even though the students are a part of multiple communities, including the global community, a national community, and a local community, the students tended to rank these influences low. Anderson’s notion of “imagined communities” (Anderson, 1991) seems to apply here; while the author applied the term to nationality (My Country), it seems that for the class as a whole, the idea of an “imagined” community applies to both the global community as well as the more local community. Juana, for example, explained, “My country, I just didn’t know where to put it…. My community, I just put it there.” As imagined constructs, the students felt they were less influential and hence the low salience scores. Juana similarly agreed, saying, “My Community, My Country, don’t really make a difference.” Just beforehand, however, she discussed the global
community which she placed directly higher than My Community and My Country:

> People around the world. So, like, by studying this you, um, people benefit from it, so, maybe, like a scientist can do stuff, and the benefits the whole world, right. So I believe that, but I don’t really think of being one, so [laughter]. That’s up here, mostly at the end.

Juana made a distinction between the global community influencing her and influencing scientists. She recognized that the global community has a bearing on the work of scientists—and that scientists’ work benefits the global community—but she does not attribute to herself the identity of “scientist,” nor does her work count as the work of scientists. Therefore, Juana’s school work does not benefit the global community, reducing the influential salience of People Around The World on her engagement in science class. These findings here are significant, given the current policy emphasis in science education on preparing for global competition and becoming a part of the scientific community. While this push may make good emphasis, these findings point to the idea that it may not sway students who sit in science classrooms.

More puzzling was that the students tended to rank My Friends as not much of an influence. Much of the push of social constructivism and Vygotskian theory is predicated on the idea that learners build understandings collaboratively and in dialogue (Vygotsky, 1978). One would assume, then, that learners would influence one another. Some students, such as Rosa, did intimate this point: “And
my friends, I guess, like labs, when I do it with my friends, I learn more. Because if I do it with people I don't know, it was just awkward, and I don't want to do anything.” More students, however, seemed to draw a distinction between friends and academic work, as Juana did: “My friends, like, it’s hard to say. Because with my friends are just like there for personal stuff and too much about school things. Maybe they’ll like help you and all that, but that’s kind of different.” When these worlds collide, the academic and the social, Rosa suggests that the learning process goes more smoothly when academic work is done among friends. When work is done with unknown or disliked students, “…it was just awkward, and I don’t want to do anything.” This is not to say that students should not be kept only within known and comfortable social zones when engaging in academic work.

The results from this rank order activity highlights the importance of relationships inside and outside of school, students’ formed identities, and their personal histories in the academic work that is being accomplished. What happens outside the classroom, from a meanings perspective, is very influential in terms of students’ engagement with science; Nespor's (1997) metaphor of “tangled up in school” is apt here. This rank order activity was very useful in elucidating the influences which were deemed important in the immediate place and time: factors such as parents, school requirements, and interests tended to be ranked highly while more proximal influences such as future careers, hopes, experiences, and communities outside the school and around the world tended to be ranked as
less influential. In a sense, the students seemed to be making clear distinctions between the figured world of the classroom and their histories-in-persons, those worlds, backgrounds, and cultures which lie outside the classroom walls. In the next section, I will describe in fuller detail the relationships between these concepts and academic work in science class and how they help to shape the meanings around science and school by exploring the historical and relational—the private rather than public—aspects of meaning in finer detail through close interviews and analysis.

**Private Meanings and the Science Classroom**

It is well established that the barrier between the classroom and the world outside is permeable, and students bring their experiences, dispositions, relationships, and meanings with them to the study of academic content. The previous section outlined a series of potential influences on engagement in the science class and the salience that students attributed to these influences. While often in teaching, research, curriculum development, and policy, we tend to focus on the cognitive processes and the subject matter of the classroom, it is necessary to be aware of students’ goals, interests, identities, and to an extent, insecurities in order to help students develop a meaningful relationship with science. From a figured worlds perspective, these private meanings grant the researcher and educator insight into the histories-in-persons of the agents involved. In terms of
the humanistic approaches to science education, these private meanings provide insights into the lifeworlds of the participants.

This section moves deeper into these influences, relationships, and meanings through the reflective dialogue of several students elicited through the one-on-one interviews. With each interview, I will elucidate each individual’s past experiences and history, their relationships with others inside and outside the classroom, and their anticipations of the future. As explored earlier, meanings can be seen as the bridges we build across time and relationships to lend coherence to experience. This section explores the aspects of meaning and science education explored above in more detail, providing a more robust insight into the ways that the teacher and students construct the figured world of the classroom. I will first provide an overview of the histories, relationships, and anticipations of Ms. Stoneham before moving on to three specific students and the meanings they bring to the science classroom. These students provided different cases of the same classroom experiences. Kimberly and Leah tend to push back against learning science, and orient their stories to justify this approach. Debra, on the other hand, seeks to learn science deeply and enthusiastically, despite the seemingly difficult dispositions, conditions, and relationships she faces on a daily basis. I chose to relate the stories of Kimberly, Leah, and Debra because their stories relate closely to other data points: Kimberly’s card sort strongly connecting activity and identity, and Leah’s and Debra’s drawings of science in action.
Ms. Stoneham: Recognizing the Teacher as an Experienced Person

Before exploring the students’ stories, it is worth noting that many of the students in their ranking of influences tended to group their teacher as an aspect of the classroom environment rather than as an agent in her own right with her own values, history, and aspirations. If they were able to hear, however, their teacher’s story, they may find that they had more in common than four hours of class time per week. As such, I will first provide an outline of Ms. Stoneham’s historical engagement with science before moving on to the students’.

**Past Experiences.** Despite her enthusiasm for the broad umbrella approach to science as gaining knowledge, Ms. Stoneham’s pathway to teaching science was one of complexity and sometimes contradiction rather than a predetermined straight line. Ms. Stoneham began her connection to science with both a positive and a negative point:

> I have always just a passion for learning and figuring things out and in particular anything to do with science. I am ALWAYS just in a very curious love for fitting two and two together and seeing how things work. And the other biggest influences why do I teach science is because in high school I had a biology teacher that was horrific and awful and ever since that day I said this class should be fun and she made it so painful and arduous that I thought you should have fun in this class. And she left in a big impact that I hated biology for that year but I loved sciences all along.

This passage demonstrates Ms. Stoneham's complex history with biology and science education as well as the provenance of many of her practices in the classroom. She saw herself to be curious, a trait that is one that is well-suited for
“gaining knowledge” and participating in science. Ms. Stoneham also discussed a negative point, in that she herself had a “horrific and awful” biology teacher in high school, so that she “hated biology for that year.” Building off that experience, Ms. Stoneham decided that her class would be different, and that “this class should be fun.”

Despite her experience in her high school biology class, Ms. Stoneham went on to study biology in college. Although in college she “…knew at some point I’d probably go into teaching,” she wanted “work experience,” first working in biology research for a year after college and then as a histologist, helping with diagnosis of pathologies based on tissue samples and conducting medical autopsies. As a past experience, she expressed that she really enjoyed teaching the lab classes while she was an upperclassman in college, but that she wanted “work experience and research and get real hands-on science” before going into teaching. While working, she gained experiences in the clinical aspects of science. Ms. Stoneham went on to say that she greatly enjoyed the work, and she gained a great deal of experience in the clinical and laboratory sciences. In the end, it was the people closest to her who provided her with the impetus to enter the teaching profession.

**Coexisting in Relationships.** In making the move from the laboratory to the classroom, it was her marriage and children who caused her to reconsider her daily exposure to chemicals and disease in her work. She explained, “I had every disease in the book as a result of working in a pathology lab, and I kept bringing
them home, and I was like, I just can’t do this anymore.” By drawing on her past experiences as a lab teacher in college and on the current situation that with the responsibilities of husband and children she no longer wanted to bring illnesses from her work home with her, and she decided to pursue a career in teaching. This is not a direct line into teaching, but instead demonstrates that Ms. Stoneham considered her options and relationships when entering the laboratory and the classroom.

**Anticipating the Future.** Ms. Stoneham’s past experiences had influential effects on her goals for her teaching and her students. In deliberating on and expressing her meanings, she made connections between her *past* experiences, her *present* situation, and a hoped-for *future* state. When asked to name the goals she has for her students, Ms. Stoneham immediately responded, “One of my goals is to make science a little bit more interesting, more applicable to their lives, a little bit of fun, and see that it’s not so bad.”

Beyond this goal, Ms. Stoneham also hopes that this class is not an end point, but a starting point. As she related to me:

Ms. Stoneham: I think if they like science a little bit more they’re going on to science, they’re being encouraged or they’re inspired to go on a little bit further.
Researcher: In terms of....
Ms. Stoneham: Either another science class or even maybe, you know what, I never thought about going into anything in science, but maybe now since my eyes have been opened to what it is a little bit more, I might go into the scientific field,
or see that there's a lot of options in the scientific field. And they that they didn't realize existed.

Ms. Stoneham is hoping that her students become inspired by her class to “go on a little bit further” and perhaps take another science class because they want to, not because they are required to. In addition, she is also thinking that she may open the doors for students to enter “into the scientific field,” to follow advanced studies and pursue a career in the sciences, to be made aware of “options in the scientific field... that they didn't realize existed.”

**Knowledge and Values.** Corrigan and Gunstone (2007), in introducing the concept of value-guided science education, drew on the work of Halstead (1996, p. 5, in Corrigan & Gunstone, 2007) definition of values:

The principles, fundamentals, convictions, ideals, standards, or life stances which act as general guides or as points of reference in decision-making or the evaluation of beliefs or actions which are closely connected to personal integrity and personal identity.

In order to build upon the nexus of past, present, and hoped-for futures, I asked Ms. Stoneham to engage in the same rank-order exercise as her students. In this sense, this activity is another way to elicit her goals, values, and meanings attributed to her relationships with her students and the teaching and learning of science. These values are important in terms of understanding in more depth the kinds of experiences, dispositions, knowledge, and identities Ms. Stoneham wishes to impart to her students. I first asked her to sort the influences as to how she would predict her students would rank them, and then I asked her to sort the
influences according how she wants her students to rank them. These rankings are found in Table 5.2.

<table>
<thead>
<tr>
<th>Predicted Ordering (Ms. Stoneham’s Categories)</th>
<th>Desired Ordering (Researcher’s Categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Home Interests</strong></td>
<td><strong>Intrinsic</strong></td>
</tr>
<tr>
<td>1. It’s A Required Class</td>
<td>1. My Interests</td>
</tr>
<tr>
<td>3. My School</td>
<td>3. My Concerns</td>
</tr>
<tr>
<td>5. Getting a Good Job</td>
<td>5. My Experiences</td>
</tr>
<tr>
<td><strong>Individual Opinions</strong></td>
<td><strong>Relational</strong></td>
</tr>
<tr>
<td>8. My Interests</td>
<td>8. My School</td>
</tr>
<tr>
<td>10. My Hopes</td>
<td>10. My Country</td>
</tr>
<tr>
<td>11. My Concerns</td>
<td>11. People Around The World</td>
</tr>
<tr>
<td>12. My Concerns</td>
<td>12. My Teacher</td>
</tr>
<tr>
<td><strong>Outside World</strong></td>
<td><strong>Material</strong></td>
</tr>
<tr>
<td>15. My Teacher</td>
<td>15. It’s A Required Class</td>
</tr>
</tbody>
</table>

Table 5.2. Ms. Stoneham’s Influences rankings, according to predicted and desired orderings.

Ms. Stoneham predicted that her students would rank the influences into three separate categories, which she referred to as “Home Interests,” “Individual Opinions,” and “Outside World.” The Home Interests she generally referred to as “requirements,” as she described It’s A Required Class, “I would think because it’s a required class for them. So they have to take it, so there’s really no choice.” She connected school with the notion of requirement, grouping the two together, because, “...the school wants them to take a certain set of things before they graduate.” Ahead of school, however, she ranked parents second, “...because their
parents want them to do well in school, or want them to have success so that they can graduate and get a job.” Ms. Stoneham connected the idea of getting a good job with parents, as “...[the students] also know a good education is going to get them a job, which I think their parents kind of stress.” She listed friends in this category because “...they like to be in school with their friends.” These influences that Ms. Stoneham listed first were direct, local, and immediate. Beyond home “interests,” however, Ms. Stoneham was also implying that she predicted that students would ranked these influences highly in order to fulfill an obligation or for the benefit of someone else.

The next group that Ms. Stoneham identified was “Individual Opinions,” listing many of the internally-focused influences, such as interests, experiences, hopes, concerns, and questions. She folded Nature/Environment into this category because when considered as content, this particular influence provides an element of interest: “Science is kind of interesting because of the environment, it has something to do with how I am going to be interested in the world.” Ms. Stoneham seemed tentative about the third group, the “Outside World,” stating that My Country and People Around The World “...might have something to do with their interest in their country and the people around the world, and how science affects my country and the people around the world.” She felt that in terms of the influences and outcomes of this group, from the students’ perspective,
“they don’t have a lot of control over.” Ms. Stoneham separated out herself from
the other three clusters, as she explained:

Ms. Stoneham: And then, just, my teacher’s my teacher.
Researcher: So what does that mean?
Ms. Stoneham: Um, it’s a requirement of the class to have a teacher.

While the Home Interests included influences which were requirement-oriented,
she seemed to place the role of the teacher in terms of a function of the class itself,
minimizing her role and her relationships with her students—at least in terms of
how she saw the relationship play out from the perspective of the students.

In other words, Ms. Stoneham predicted that her students would rank the
influences in terms of requirements and the benefit of others most highly, their
individual sense of themselves next (in terms of their internal interests and
questions), and factors beyond their control—the outside world—last. She
predicted that she herself, as their teacher, would not significantly figure in as an
influence in the students’ engagement in science class as she conveyed to me that
the teacher is merely a part of the class experience itself. Ms. Stoneham positioned
the teacher as an element of the “science class” field, rather than an agent that can
influence students’ engagement with science in the classroom.

I then asked Ms. Stoneham to order the influences again in terms of how
she would desire her students to complete the activity. The categories identified in
Table 1b were not labeled by Ms. Stoneham, who focused on rank order rather than
categories as she had done in the first round. I categorized her ordering by
considering the connections she attributed to the influences. Her ranking fell into three categories, from highest to lowest: Intrinsic, Relational, and Material. It should also be noted that Ms. Stoneham used qualitatively different language when describing this round of rank ordering. Because of the nature of the task and instructions, one can interpret this ranking as a way of Ms. Stoneham conveying the values and meanings that she wishes to share with her students.

The first cluster—the Intrinsic cluster—was comprised of many of the inward-oriented influences, but Ms. Stoneham described this group in such a way as to accord agency to students in science learning: “...they would find it interesting, and because they're interested in science and they want to know more about science...” (emphasis added). Experiences and hopes were framed by Ms. Stoneham in terms of students actively drawing on their past and having an impact, as she related, “Will my experiences benefit me, or how can I apply them. And maybe their hopes are that I can make some kind of change, or effect on the world.” Through this first cluster, Ms. Stoneham is describing a desire that students be intrinsically motivated to want to learn science and to bring about beneficial change with this knowledge.

The Relational cluster was next in Ms. Stoneham’s rank ordering. Whereas in her predicted ordering she classified these relationships as either determining the behavior of students or out of the students’ control, in her desired ordering she reframed these influences to represent beneficiaries of the students’ activities. For
example, in her predicted ordering, Ms. Stoneham connected “My School” with “It’s a Required Class,” indicating that the two were intractably related; in her desired ordering, she framed “My School” in terms of helping to build “…a nice school community.” In addition, she indicated that My Country and People Around The World would only figure tangentially in her predicted ordering, being outside of the students’ control. In her desired ordering, however, Ms. Stoneham wanted her students to “…place some value, or some interest, or some connection to the, their country and what science can do, what they can do for their country as far as improving it, and improving the people around the world.” She wanted her students to not only be intrinsically interested in science, but also to recognize that they can do good works with it for the benefit of communities.

Lastly, Ms. Stoneham recognized “Getting a Good Job” and “It’s A Required Class” as Material influences which both influence and structure students’ engagement in science class, although not strongly. She indicated that science class, “…should help them get a good job, and the bottom thing is it is a required class.” By placing these concrete, material influences last, Ms. Stoneham was, from a goals and values perspective, not placing a great deal of importance on them. She recognized that they were necessary aspects, but she was hoping that her students would engage in the path of learning as intrinsically-motivated individuals who are able to affect positive change in the world with science. These
values are consistent with the liberal humanistic model of an educated person elucidated in the Literature Review.

Ms. Stoneham made clear that providing students with options in their future, to expand their notions of what is possible and how they may set their goals, is a long term and a much more important goal. While describing her roles as teacher, as discussed in the previous chapter, it is interesting to note that these larger experiences, meanings, and values gave way to the nitty-gritty day-to-day responsibilities and management of details. Yet we can see that these values and meanings lurk behind the day-to-day. Without the explicit inclusion of these larger goals, values, and experiences into the roles of the teacher, students are not able to see the full extent that their teacher is a fellow person, nor are they able to understand the full extent of the hopes that Ms. Stoneham holds for her students. Yet these are the “private” aspects of an individual’s identity. How private meanings may be bridged to public roles and activities will be discussed further in the Discussion chapter, but now I will delve into the histories, meanings, and experiences that several of the students’ bring to the science classroom.

**Listening to Students: Experience and Participation**

Despite Juana’s earlier admission that she has not had a great deal of experiences due to her age, it can be argued that whatever those prior experiences are have a great deal of bearing on the practice of the classroom. Beyond the cognitive aspect of building upon prior knowledge to encourage learning, the
students bring a number of experiences, meanings, and hopes—their histories in person (Holland and Lave, 2001)—into the science classroom which influences their participation, relationships, and achievement. The negotiation of these personal experiences and meanings with what is valued in terms of practices, discourses, and outcomes contribute to the “figuring” of the world of the classroom and how individuals’ identities play out (Urrieta, 2007). The students shared these with me through the narrative of their interviews, and were often expressed as stories. I will introduce the stories of Debra, Leah, and Kimberly in order to better understand the ways in which students negotiate, discover, and bring meanings in the science classroom and around the science curriculum.

While this negotiation has the potential to help students and teachers experience more than a conventional science curriculum, what is valued in the figured world of the classroom is often deeply and culturally entrenched (Carlone, Haun-Frank, and Webb, 2011).

**Debra: Memories, Hopes, Fears, and Language**

Debra is an excellent case to compare with Ms. Stoneham’s. Similar to Ms. Stoneham, Debra expresses a relatively high degree of intrinsic motivation to engage and participate in science class. Debra’s experiences and influences are quite different than Ms. Stoneham’s, yet the enthusiasm is very much the same. As a temporary resident of the United States from Brazil she found her English language skills to be an important mediating factor in her learning process.
Debra shared with me that her parents are divorced and both are remarried. She was brought to Cotstead by her father who was seeking employment in the US. She lived with her father, her step-mother, and a newborn sister. Her mother, her step-father, and a younger brother were still in Brazil, along with her extended family. A diagrammatic representation can be found in Figure 5.1. These relationships are important to Debra and figure strongly into her meanings of science class. I will discuss these relationships in detail later.

![Figure 5.1. Diagram of Debra’s family relationships and locales.](image)

**Past Experiences.** Debra was one of the few students in the class who expressed that she enjoys learning science and participating in science class on a regular basis. When asked what she enjoys about science class, she responded:

> Because I like to know how life works, and like to gain knowledge and... ‘Cause especially, ‘cause I want to be a doctor, so, or a biologist, so I have to know those stuff, and I find it really interesting.
In her response, Debra utilized the same language that Ms. Stoneham had used in conversation and in her teaching, in terms of understanding how life works and gaining knowledge. However, Debra also brought in her own goals, to pursue a career in medicine or biology. She said that she had wanted to go into the sciences as a career since childhood, “‘Cause I grew up, like, my grandma has a farm so I used to go to her farm every weekend, so I grew up with the nature kinda, with the environment.” Her past experiences of spending time on her grandmother’s farm helped her to appreciate nature and to propel her towards a career in the sciences.

While her visits to her grandmother’s farm exposed her generally to nature and the environment, Debra brought up another experience which reinforced her interest in science and her choice to pursue a career in biology or medicine. She recalled her experience in helping with and seeing the events leading up to her baby step-sister’s birth:

She [step-mother] had a baby so I followed her pregnancy and I got to watch the, like the labor. And it was really amazing. ‘Cause I wanted to, when I say I want to be a doctor, I want to be a midwife, so, it was like a great experience. It was like, oh, that gives me an idea of how it’s going to be like. And I got to help them too. It was really cool!

Not only was she granted access to see her step-mother’s labor process, she was also asked to help out. At this point she clarified her career goals to becoming a midwife and Debra saw this experience as an opportunity to practice this role providing her with “...an idea of how it’s going to be like.” It should be noted that
in the rapidly changing social and economic climate in Brazil, midwives are playing an important and progressive role in the establishment of women’s rights (Carr & Riesco, 2007). I will point out later and in more detail her commitment to using science to bring about change; suffice it to say that in this passage, Debra’s commitment is reflected here. As her evaluation of the experience sums it up (“It was really cool!”), it seemed as though she not only appreciated the experience of her step-mother’s labor, but also used it to strengthen her commitments to her future career goals.

Coexisting in Relationships. As mentioned earlier, Debra’s familial relationships are both complex—spanning a divorce, two re-marriages, a close-knit extended family, and two continents—and influential. In discussing her relationship with her family, Debra implied that wanted to share her interest in and knowledge of science with her family and to make it a part of who she was in relation to them. When asked if she discussed science or biology class with her family, Debra replied:

Not really, because they are not really interested in that stuff, and when I start talking about that, they say, oh, my gosh, here she comes again! [Debra,] with her biology stuff! ... [T]hey find it very annoying. They’re like, oh, just because she likes it, and she knows a bunch of stuff, she thinks she’s better. But I’m like I don’t think I’m better. I just want, I just want to share it with my friends and with my family.

Debra described a situation in which she sought out an adult family member to share her interest in and devotion to science. She was not only rejected but cast as
arrogant and self-important in what seemed like an influential experience for her. When asked to elaborate and explain, she indicated that she received this treatment from her stepmother. “She's like, oh, here comes [Debra],” Debra related in a sarcastic tone, in an attempt to imitate the voice of her stepmother. “She just, she pretends to be nice sometimes, but I don’t know if she really is....”

Debra also discussed the influence her extended family has on her studies. She distinguished between the family on her dad’s side and on her mom’s side, casting her family on her father’s side as more supportive of her studies than her mother’s. She also framed her explanation in terms of schooling in general, not just learning science specifically:

My dad’s side, they support me, but my mom’s side, they say it’s very hard, you’re not going to be able to go to college, just because they didn’t go to college because they didn’t want to. They weren’t dumb. I don’t want to put it that way, but they just wanted to have fun, and not study, so. It’s a pretty un-smart decision to make as a teenager, so. It’s not my fault that they have a bad life.

Debra expressed the idea that her mother’s extended family made a “pretty un-smart decision” in not choosing to attend college. She denied that her family was “dumb,” but she explained that they made poor choices and so “they have a bad life.” Debra indicated that her mother’s family is imposing their own frame of reference and experience on to Debra, so that if they didn’t go to college, neither would Debra. But Debra pushed back against this projection and rejected the
pathway she felt they themselves chose for themselves by working hard in school and setting goals for herself of college and a career in the sciences.

While Debra didn’t feel like she could share her interest in the sciences with her family, she did have a friend outside of the class, Constança, with whom she felt she could relate. According to Debra, Constança shared her interest in the sciences:

No, but with my friends, I have just one friend, Constança, she loves biology too. And then we just talk about it, how, evolution works and stuff. And we share, I share with her what I learn in this class, and then she shares with me what she learns in chemistry class.

While we can assume that both Debra and Constança share a number of different kinds of experiences, experiences in the classroom—and the science classroom specifically—are included in their dialogue and the structure of their friendship. As Brickhouse and Potter (2001) pointed out, if engagement in science is deemed a marginalized activity and not valued as a form of identity-formation within one’s social sphere, continued participation is made much more difficult. This friendship and common interest is a way that Debra and Constança are able to stem these other influences and build value for each other’s interest in science.

Anticipating the Future: Models of Success. In addition to familial and peer relationships, Debra also pointed to a role model from television as an influence on her engagement in the classroom. This television personality was
Richard Rasmussen, on the Brazilian nature and science program *Selvagem ao Extremo* (“Wildness to the Extreme”):

When I was little, I used to watch a show in Brazil, this guy was a biologist, and he was like really famou-, not famous, but he was really respected, and he’s really respected in my country. So like he’s my role model, I want to be like him. He’s really smart, he’s really a wise guy, so I want to be like him.

Debra is highlighting the fact that Richard Rasmussen is “really respected” and “really wise” in the eyes of the public. These characteristics resonated with Debra so she aspired to “be like him.”

But there was another way that Debra aspired to be like him, in terms of the way Richard Rasmussen talked and expressed himself:

I want to be able to talk about science and pronounce the words. Even in Portuguese, it’s kind of hard, there are many big words, he [Richard Rasmussen] talks about it without a problem. And he helps people too, he helps the environment, so I want to, I think that’s what’s a successful career. He had a goal and he fulfilled what he wanted.

She noted that Richard Rasmussen was able to “talk about science and pronounce the words... without a problem.” Debra also described her idea of a “successful career,” framing markers of success in terms of helping both people and the environment. She further saw success as having a goal in the first place and fulfilling that goal. Presenting Richard Rasmussen as a model, Debra described success in terms of being able to communicate clearly about science and being able to fulfill one’s goals.
This desire to be able to talk about science clearly, using “big words,” was reflected in other instances as well. During the Public Service Announcement activity, Debra blurted out to her group, “I hate my stupid accent.” I asked her to explain how her accent connected to learning science, to which she replied:

Debra: ‘Cause there are some words that I find it difficult to pronounce and then people make fun of you, like a lot.
Researcher: Oh. Did somebody in your group make fun of you?
Debra: No, not in my group. Like before, like back then, when you weren’t even here.
Researcher: Oh, OK.
Debra: They used to make fun of me and stuff. They stopped.

She described science as a course needing both a particular vocabulary and a particular way of pronouncing this vocabulary. As a student learning English (she did not know any English prior to her entry into the United States 20 months prior to this study), she was unable to utilize and pronounce the specialized vocabulary with the same ease and facility that her peers seemed to already possess, and therefore she said that her fellow students “…used to make fun of me and stuff.” Debra said that she was no longer being made fun of, but those kinds of feelings and inadequacy despite her strong interest and desire to succeed in the sciences.

**Anticipating the Future: Status and Fears.** There is another side to Debra’s optimistic and progressive attitude to engage in and use science. Not only is she fulfilling an interest and building towards a goal, Debra is also staving off a fearful future, a specter expressed to her by her father. When asked why it is important to know science, she responded:
It’s important to know, ‘cause like being a scientist or biologist, it’s like it’s the future stuff. ‘Cause evolution is happening really fast, and we don’t know what’s going to happen to the world. And we have to find, have more technology, so we can help people in the future. ‘Cause many bad stuff is going to happen. And, doctors and biologist, they, always, like they always will be needed. If the world is about to end, no one is going to need like a singer and stuff, kind of. That’s what I think, what my dad taught me. Because no one is going to like need a dancer, they’re going to save the important people. Do you know like, was it, World War Two, that Hitler, was it Hitler, right, that killed the useless people, and they just kept the famous people that they needed, like such as doctors, and like, and even though he was like a, he had, he used music, but he wasn’t an important guy, so, my dad says you have to be important, so they’re just not, they’re not gonna kill you when you grow up if anything bad happens. So they’re gonna need me. Hopefully!

While her account contained a mixture of dystopian elements of science fiction novels and historical inaccuracies, she was doing her best to make sense of and interpret some apparently quasi-prophetic statements by her father. She was granting urgency to her career path as well as a need to appear intelligent through the use of language. By sounding intelligent, she would be needed during some human-wrought apocalypse. By being important, “…they’re not gonna kill you when you grow up if anything bad happens.”

This strong dissonance between being fearful of an imagined future apocalypse, pushing back against unsupportive relatives and finding a kindred spirit in a friend, desiring to help through science, and drawing upon early formative experiences with the natural world make for a very interesting person and an interesting perspective on engaging in science class. These are deep and
serious issues that Debra is negotiating, as well as an impending return to Brazil at the end of the school year. Debra treated this negotiation as an opportunity to struggle and succeed, even in the face of a language barrier. She worked hard and deliberately to figure her own identity within a classroom and world filled with barriers. While Debra engaged—even if from a strong yet dissonant base of experiences, relationships, interests, goals, and fears—not all students in the class approached the classroom experience in the same way. Kimberly and Leah, for example, while not facing the kinds of structural and relational issues, approached science class very differently.

**Leah: Confronting the Brick Wall**

Leah is an “average” student, both in terms of her grades and in terms of her participation. Despite the fact that she is quite social (and in fact, at the end of an interview she asked permission to send a text message back to one of her friends, a form of interaction not allowed during regular class time), during classroom discussions she tends to take a step back and only participates when called upon. Her family was a member of the white middle class in Cotstead and they speak English at home. In Ms. Stoneham’s biology class, at least, she befriended Gabriel, preferring to partner with him in small group activities and often chatting with him during the downtimes of class.

Leah voiced a compelling metaphor for her passive engagement in class, that of a “brick wall” coming down between her and her participation. Traces of
this “brick wall” can be found in her past experiences, her relationships, and her plans for an anticipated future. But first, I will document an exploration of the “brick wall” itself.

**Raising the Brick Wall.** While Leah was not enthusiastic about science class, she said she enjoyed taking business classes. I asked her to describe the differences between her business and biology courses:

Well, I take a business course, and it’s pretty much notes, that’s it. But it’s pretty much, it’s like an environment where you can talk to the teacher, you can talk to like other students without being like, shuddup. You know what I mean? But I mean like other classes, like, they’re all the same. You take notes, you do activities, you do like stupid stuff like that, but it’s aggravating, ‘cause like biology’s a main subject, math’s a main subject. OK, I don’t like those, because too much thinking—

Leah mentioned that while the classroom activity structures in her business and science classes were relatively analogous—taking notes on what is said in class—she felt she was afforded an environment in her business course where she could “talk.” She said that she could talk to the teacher and talk with other students without being told to “shuddup.” She moved on to say that biology and math, as examples, are “main” subjects. It is likely that by “main” she is referring to the idea that these courses are required, unlike her elective business courses, but she also described these courses as requiring “too much thinking.”

I then asked Leah to describe “thinking” for me, and she responded with the brick wall metaphor:
Leah: Learning something new is hard when you’re kind of in a mindset, where you like what you know. If that makes sense.

Researcher: Could you tell me a little bit—

Leah: Well, I’m happy with what I know now, I won’t feel like I need to know more, I already know that the stuff I’m learning now isn’t really going to help me. So it’s just like this big brick wall that just like shows up, that doesn’t want to let information in because it’s just like how is this going to help me? Like there’s no point in learning this.

Before moving on to the brick wall, it is interesting that Leah linked “thinking” with “learning something new” when “you’re kind of in a mindset, where you like what you know.” For Leah, “thinking” is required when something new challenges her current trajectory, perturbing her mindset. When Leah noted that in the mindset “where you like what you know,” what one knows is larger than just content, but also a pathway with a set of aims, goals, and practices. When learning something that “really isn’t going to help me,” that is, learning something that may challenge her trajectory, “this big brick wall that just like shows up.” Leah’s brick wall “doesn’t want to let information in,” but by doing so, the brick wall is constraining Leah to a particular pathway even more so, effectively shutting out alternate opportunities. Where this pathway arose for Leah can be found in past interactions and experiences and the relationships with her parents.

**Past and Present Experiences and Relationships.** Leah chose her trajectory when she was younger, and it appeared as if she would not waver from that trajectory. Leah declared that she will go into business like her father—and,
in fact, she plans on taking over her father’s commercial cleaning business when
she is old enough. I asked Leah when this decision was made, and she responded:

I think it was right after I just got out of middle school, I just finished
8th grade, and I had to pick electives. And I went up to my dad and I
said, I don’t know what I want to take. And he said, well, he said, in
my personal opinion, you could take a business course or an
automotive class. And I’m like, I’m not going to take an automotive
class, are you kidding me? And then I took, um, so I was like,
 alright, whatever. I asked my mom, and she was like, oh, you should
do like knitting or something. I’m like, yeah, I’m done. So I was like,
well, I’ll try business for a year, see what it goes. So I went to intro to
business, and I liked it. Like I caught on, it was fun, I enjoyed it. So,
I’ve been working with my dad since he started [his own business],
which was like six years ago.

As Leah was deciding on electives, her father encouraged her to take an elective in
something that they shared together; Leah had told me earlier that she was her
“daddy’s girl,” and worked with him on his own business and also worked on cars
with him. She also looked to her mother and asked for advice. Although it is
likely that Leah’s mother did not recommend knitting as an elective per se, it is
likely that what she suggested did not seem “useful” to Leah. Leah’s experience in
her business course, however, she found both useful and enjoyable. She was able
to connect what she was learning in those business courses to working with her
father on his own business. The elective choices were positioned in such a way as
to build upon the relationships that Leah and her father were developing. It
should also be noted that when given the opportunity to engage in a new pathway
or to develop a new interest, Leah turned it down in order to follow the course in
which she could continue to relate with her father.

I further asked Leah about her relationship with her father around his
business and her intent to take over from him:

So he was always like in business. So now he owns his, and then, he,
he kept on bringing it up, and he’s like, well, is this what you want to
do, do you want to go into business? I’m like, well, so far, I think
yeah. And he’s like, well, OK. Well, he was like, well, you know
what I do, ’cause like I see him like make up the bills for the thing,
and I see him like pay people, like you know what I mean, like I’ve
been a part of that? So he’s like, well, how’d you feel about taking it
over one day. And I’m like, well, I don’t know. I don’t know, it’s
kinda gross. And he’s like, well, you know, you make this much a
year, you give that, like you know what I mean? Like he explained it.
And I was like, well, I don’t know. And then I thought about it, and
I’m like, well, what would I do if I didn’t have that? And I couldn’t
see myself doing anything else but running his business. So that’s
really all I need.

Although I am uncertain as to when in Leah’s life her father asked if she would like
to take over for him, it was a foundational experience for her, providing her with a
pathway and a sense of purpose. Leah mentioned that she participated in the
practices of business with her father since he started out on his own, and enjoyed
spending that time with her father as well as the work. Her first response was one
of uncertainty and even with an inclination to reject his offer, feeling that “it’s
kinda gross.” After her father explained the parameters and expectations of
running her own business, she decided to acquiesce, framing her decision in terms
of her potential future and her identity: “…what would I do if I didn’t have that?
And I couldn’t see myself doing anything else but running his business.” What she said next laid the groundwork for her straight-and-narrow trajectory—“So that’s really all I need”—allowing her mental brick walls to block other options and her engagement in thinking, learning, and activity that either challenged or did not unswervingly and instrumentally align with her chosen pathway.

Leah felt like she made her choice and resented any attempt to change—or broaden—her possibilities for choice. She knew her interests, was aware of her goals, and anything else was extraneous, even if it was required, like biology class:

> It’s just, I don’t know, I’d rather not learn this stuff. It’s not what I’m interested in. ‘Cause I’m being forced to take this class, well not forced, but I mean like, it’s a requirement. So I don’t have the personal choice of what I want to take, so because I’m in this, it’s just like—brick wall—why am I here?

Leah resented the required nature of science class, even referring to being forced to take the class (even if she did tone down the language in retrospect). Even if learning science has the potential to expand her opportunities, she saw the required nature of science class as limiting her choices, preventing her from learning what she wanted to learn. In the face of that force, she attempted to limit the influence of the required class and the brick wall came down.

**Anticipating the Future.** Leah feared that her mediocre performance in science class would have long-term effects for her opportunities, especially for college. She confided in me that she wished to attend college, preferably one that
focused on business as a way to safeguard against future failure. Recognizing the impact her grades would have on her admissions process, she related:

Leah: Honestly, I'd rather just stick in business. That's it. 'Cause that's where I'm going, this isn't going to help me pursue my future at any point. If anything, it's only going to bring me down when colleges look at my thing, like you know what I mean? It's not an interest of mine.

Researcher: Because of your grades, do you mean? Or because-
Leah: Well, I mean, my grades aren't great. I'm an average student. Sometimes they go a little below the C's, but never an F. But because I don't like this class, it's hard for me to pull in what she's trying to say, so it's just like, because it's not a class that I want to take, I feel pretty aggravated that it's just like, I don't want to take this, but my grade is low, colleges are going to look at that, and they're going to be like, Oh [interested look]! Oooooo [disappointed look with furrowed brow]!

Again, she denied the utility of biology class “to help me pursue my future at any point,” conflating utility with interest. That is, because science is not useful, she is not interested in it. She continued that because it is difficult for her “to pull in what she’s [Ms. Stoneham] trying to say,” she felt “pretty aggravated.” Biology was a class she neither wanted to take nor found interesting or helpful, and she worried the grades she was getting would prevent her from entering college.

Revisiting her card sort results from the previous chapter, Leah tended to strongly link activity and identity. For example, her three categories were comprised of normal people engaged in everyday activities, normal people engaged in scientific activities, and scientific people engaged in scientific activities. She delved into these ideas in our one-on-one interview:
Leah: Well, I personally can’t really use it unless you go into the field, like you know what I mean? Like, go deeper into it. Like, I don’t really, I’m not too sure, to be honest.
Researcher: So the only way to use science is by going into science?
Leah: Well, no! I mean, there are other ways of using it, but stuff like that, how am I going to use that, if I’m just going to live an average life, going into business? Like, that’s not, there’s no way that’s going to fall into place.

According to Leah, the depth that science is covered in biology class is not useful “unless you go into the field,” that is, your activities and identities are altered to account for the depth of understanding. For her, who saw herself as “...just going to live an average life, going into business,” by creating a safe space and keeping participation in science at a distance, she is protecting her identity as someone with a clearly defined trajectory.

This exploration of meaning-making through Leah’s eyes leads to a consideration of “usefulness” in terms of biology and science. Ms. Stoneham cast science as a process of “gaining knowledge” and did point to its utility in terms of understanding life, health, and potential future offspring. In Ms. Stoneham’s conception, by living—or being living beings—knowledge of biology is useful. Leah’s guarded participation due to her tendency to tightly link identity and activity provides a different perspective.

Knowledge and Use. The concept of “use” when applied to knowledge implies a sense of value or currency, that the knowledge learned in a particular class will grant a student some deeper understanding of a situation or
preparedness in terms of a response to a situation unavailable to them without that knowledge. When asked to explain why learning biology is important, Leah provided an ambivalent response; she indicated that there were aspects of biology that she wanted to learn and aspects she did not:

Leah: I think it's important for the fact that you're going to know how the environment works, and you're going to know how the parts of your body work, and you're going to know about cells, and you're going to know what you could possibly pass on to your children. I think that's important. I think that's something that you should know. But it's just like all the little stuff that goes in there. But it's just like, 'cause there's certain things that I DO want to learn, but it's just, the extra stuff that's thrown in there isn't needed.

Researcher: Can you give me examples of both things that you want to learn and then things that aren't needed?

Leah: Well, like, OK, alright, here we go. So like, if I'm passing a trait down to a child that I may have, I want to know what their possibility is of having that trait, if it's good or bad, so I can know, OK, well they're going to have to go get checkups or they're going to be fine, or, they have to go to the doctors, they have to go to SOMETHING. You know what I mean? But then it's just like, if I have to learn something about like the chromosomes and how they're made, and formed, and how they can tear apart, I don't care about that! Like, how is that, like that happens naturally, you don't need to, you know, I'm not going to do that myself... per se, I guess.

Leah's example of the aspects that she did want to learn tied closely with having the information and protocols necessary for interacting with other people. She would know that her child could inherit a trait, and if so, what kind of medical attention to seek. In terms of what she did not want to learn was the underlying mechanisms and processes, “the chromosomes and how they're made, and formed,
and how they can tear apart,” as this “happens naturally.” So for Leah, utility implies that knowledge has an actionable component to it and does not necessarily incorporate a deep understanding of processes and mechanisms.

Leah further emphasized these points when asked what she would do to change how science class is run: “I wouldn’t teach the small stuff, I wouldn’t have vocab words that aren’t going to mean anything ten years down the line that I’m not even going to remember.” Leah expressed a resistance to “the small stuff” and the “vocab words that aren’t going to mean anything ten years down the line.” These details and this particular language was not seen as useful in terms of “help[ing] you get into what you want to get into,” particularly if one is to “live an average life, without science.” This was yet another clear distinction between “every day,” “normal,” or “average” on the one hand and “science” on the other.

Leah’s participation in and meaning-making around science class and the science curriculum was inexorably linked with her sense of identity. Her sense of identity was predicated on satisfaction with a chosen career trajectory, taking over her father’s business, and she resented the idea that she was being required—having choice taken away from her—to learn something new when she was happy with her choices and her understandings of what she needed to know. In order to protect this identity, she erected mental “brick walls.” This perspective colored not only her meaningful participation in class and activities, but also her understanding of what counted as the utility of knowledge. For Leah, because her
identity is so strongly and intractably figured, curricular “interventions” which would challenge her trajectory including those based on the humanistic approaches to the science curriculum, would have to be deliberately introduced in a way that simultaneously connected with her existing sense of self and allowed opportunities for her to practice new ways of being and acting in the world with science and to see herself in a new light drawing on and using science.

Kimberly: When Science Falls Flat

When Kimberly entered Ms. Stoneham’s prep room, which I was using to interview students individually, she came in tentatively and turned down my offer for a chair. She said that she felt more comfortable standing and leaned against the counter which ringed the small rectangular room. Kimberly was typically quiet in class, only responding to questions (usually with the correct answer) when directly asked and she did not usually chat voluntarily with the other students during downtimes in class.

Kimberly’s story is different than both Debra’s and Leah’s. Kimberly exhibited a sense that she didn’t really care deeply about science class or even about school, although her grades were high for the C-block class and she was in the honors level classes of history and English. Ms. Stoneham encouraged her to sign up for the honors science class the following year, but Kimberly declined. She related to me that “honors is hard,” and she was not interested in putting in the
extra effort for an honors science class despite the fact that, from her own
admission, she was getting A’s in her other honors courses.

I asked her to compare biology class with her other classes, intending to
receive a comparative judgment of some kind. Instead, we engaged in the
following exchange:

Researcher: So how does biology compare to some of the other
classes, your English or math or history classes?
Kimberly: I don’t really notice anything, but we’re reading about
people, and people are living.

At first, it was apparent that she thought I was asking her about the content of her
classes, so while she didn’t “really notice anything,” she did mention that in other
classes, “we’re reading about people,” and building on the definition of biology
shared by the class, “people are living.” I followed up by asking her if she liked
other classes more than biology. Kimberly replied:

Kimberly: They’re all the same.
Researcher: They’re all the same. So does that mean you like
them—
Kimberly: The same.
Researcher: The same?
Kimberly: Yeah. I don’t have a favorite class.

In Kimberly’s estimation, all classes are the same in terms of how much she likes
them. She does not like one any more than another. Kimberly may have felt
uncomfortable sharing her judgments of her classes with me, as Kimberly was the
first student I interviewed and her posture and stance in the room—standing with
her arms folded rather than sitting—indicated that she was indeed ill at ease with
a relatively unknown researcher. However, if her first instinct was to consider classes simply as content—rather than process or experience—there is little by which to distinguish between her classes. If there is little by which to distinguish them, there are few criteria for judging them and deciding on a favorite class.

Therefore, in Kimberly’s estimation, classes were “all the same.”

Knowledge, Growing Up Stupid, and Success. This indifference towards her classes, and biology especially, seemed to color many of her responses. When asked what her parents might tell her as the importance of going to school, Kimberly replied, “So I can get a good education and get a good job. If I get a good education, I can get a good job.” Similarly, Kimberly described biology class as one course in a string of courses on a path to career in the sciences:

Researcher: Why do you think the school said, you have to take biology this year?
Kimberly: So that you’ll be ready for next year, and the year after, if you decide to take science, when you grow up, and be a scientist or something.

Although Kimberly sees taking biology as one step in a line of developmental processes, at some point she felt that the logical endpoint would be to become a scientist. Kimberly made it clear that she was not interested in becoming a scientist, reinforcing an affect of indifference towards her classes in general and biology in particular. If she did not want to be a scientist, Kimberly did not need to feel anything other than indifference towards her science classes.
Kimberly received more than adequate grades which did not reflect her stated indifference. In trying to understand this discrepancy, we engaged in the following exchange:

Researcher: So, do you like to learn?
Kimberly: I guess so. Except I don’t, so I don’t grow up stupid, I want to know things.

She responded ambivalently (“I guess so”) to the question of liking to learn.

Kimberly then followed up with not wanting to “grow up stupid.” At first she was taken aback that I had written the word “stupid” down, but then became comfortable with the idea that she could speak more openly with me. In this exchange, she began to frame school and learning as a way to safeguard against growing up “stupid,” because she “want[s] to know things.” In Kimberly’s equation of classes to content, school would provide her with things to know.

I asked Kimberly to explain more about her conception of “stupid,” now that she felt more comfortable sharing these ideas with me:

Researcher: What would you say a stupid person looks like? Or how would they act?
Kimberly: Um... they act like they don’t know anything.
Researcher: So, what are the things that they do. Like, what can’t they do, or—
Kimberly: They probably... can’t read, can’t write. Get like the [unknown], is that illiterate?
Researcher: Illiterate.
Kimberly: They probably can’t talk—very well.

In describing what a “stupid” person might or might not do, Kimberly at first states that “they act like they don’t know anything.” Kimberly described a “stupid”
person as a person who doesn’t know anything, rather than a “stupid” person is someone who exhibits a particular form of behavior. What one knows—or rather, what one doesn’t know—is a categorical property of being stupid. When I followed up with her to describe particular actions and activities, Kimberly fell back on basic skills such as an inability to read and write, equating a stupid person with being illiterate. The inability to read and write can be masked in typical everyday interaction; so, Kimberly also brought in the idea that “[t]hey probably can’t talk—very well.” Not being able to express oneself verbally is difficult to mask. We can infer that for Kimberly, like Debra, the ability to communicate capably is an important skill to master in order to not appear “stupid.”

Even though “stupid” seems like a particularly judgmental word, there is still little actual understanding of why not appearing stupid is important. When I asked Kimberly, she tied acting stupid to not being successful:

Researcher: And, so, why is it important not to act stupid?
Kimberly: ‘Cause if you act stupid, you won’t be successful.
Researcher: And successful is—
Kimberly: Probably get a good job, an education.
Researcher: What would you say is a good job?
Kimberly: Um— like a lawyer, something that pays good.

Kimberly laid out a chain of events, from acting stupid to not being successful. She contrasted this pathway to a successful one in which one “get[s] a good job, an education.” When asked to give an example of a “good job,” Kimberly replied, “a lawyer, something that pays good.” A high salary is a mark of success, and being a
lawyer is one job in which one can get a high salary. When this perspective is coupled with her sense that the reason for taking biology as a sophomore in high school is to fulfill a sequence of events that lead through a chain of science courses that end in a career in the sciences, Kimberly’s disaffected attitude towards science class is understandable. As with Leah, providing Kimberly with opportunities to extend her meanings and sense of self with science within a figured world would be a challenge. While with Leah ensuring a connection with her current identity and trajectory would be key, Kimberly may need an experience which causes a seismic disturbance for her to consider herself, her meanings, and her experiences in a different light in terms of science.

Personal Meanings and Learning and Teaching Science

Debra’s narrative was one fraught with fears, insecurities, and the lack of a stable social support network. However, her story was also filled with hope to successfully participate in science and make a difference, even if some of this hope was grounded in fear. Leah expressed a life’s narrative in which the denouement was already authored. Fearing that learning new ideas might disrupt her trajectory and sense of self, she erected “brick walls” and found the level of detail in science that she was expected to learn both difficult and useless. Kimberly, while doing well in science class so that she did not appear “stupid,” did not particularly like the class, but neither did she dislike it (or any of her other classes for that matter). She saw school as a way to master appearances on the way to a good salary,
although was wary of science in particular due to a chain of events which would likely end in a career in the sciences. These narratives were reflected in each of the students’ practices in class, from Debra’s earnest yet cautious participation, to Leah’s chatty disposition in small group and partnered activities, to Kimberly’s quiet and distanced involvement. But it must also be remembered that the class was influenced by Ms. Stoneham, the roles she prescribed for herself as teacher, and, to a much lesser degree, the experiences, meanings, and values she brings to the classroom. All of these are negotiated publicly through the practices and activities of the science classroom, even if the ideas are often kept private. The negotiation of meanings through activity in the science classroom is discussed in the next section.

**Negotiating Meaning through Activity**

As described in the Methods section of this project, several activity structures were developed to help bring different entry points, meanings, and identities in the science classroom to the foreground, addressing the research question What are the meanings that arise when students are provided the structures and activities to explicitly negotiate meanings around the science curriculum? These activities will be described in turn. The Gallery Walk—in which the students engaged twice—is discussed thematically, the Role Play is discussed in a way that describes the unfolding of thinking and relationships over time, and the Storyboard is discussed in a case-based manner.
The Big Idea and the Gallery Walk

Ms. Stoneham and I asked the students to engage with and reflect on the content they were learning by creating posters in response to Klafki’s Questions (see Methods chapter). They then hung up their posters around the room and compared and contrasted what they all represented on their posters. During our working session, Ms. Stoneham told me that her students weren’t used to thinking about “big ideas,” as is stressed in the translations of Klafki’s Questions. She said that the teachers in the school used to make use of the “big idea” concept, but it was the teachers who would provide the big idea to the students much like the teachers provide the state standard that they are covering that day. She said that she found the activity compelling because it asked the students to tease out the big ideas themselves from their learning. Over the course of the activity, both Ms. Stoneham and I encouraged the students to be creative and to express themselves as they saw fit. Ms. Stoneham also emphasized to the class that they were not being graded, hoping to provide them with greater leeway for expression.

Framing and Introducing the Activity. In introducing the activity, Ms. Stoneham said to the class, “We’re going to think about why we are learning science. Why is it important to learn what you are learning in this class?” During our working session, Ms. Stoneham and I agreed that we would frame the activity in terms of asking them the question, “How does science fit into your life?” She further introduced this question and wrote it on the board for them to refer to
while engaging in the activity. As such, the activity was oriented in its enactment around providing a structure for students to explore science knowledge in use.

**Social Interactions.** As the activity was beginning, Beryl asked me, “Is this going to be in the magazine article you’re writing?” I clarified with her that the activity is going to be in the book that I’m writing so that I can graduate (this dissertation). She replied, “That’s pretty intense.” At this point, all of the students were listening in and nodding in agreement. Both Ms. Stoneham and I told the class that they were not going to be graded on this activity, so that they should feel free to express themselves as they saw fit. However, it seemed as though this new piece of information, that they were helping me to accomplish something, provided the activity a sense of importance in the students’ eyes.

I was moving around the room, supporting Ms. Stoneham in responding to questions that the students had, and I stopped at the lab bench occupied by Leah, Margarid, and Beryl. The group decided that they wanted to include a sea animal as a part of their poster. We discussed how they might be able to do so given their self-perceived artistic abilities (they decided on a five-pointed star fish), and I helped them refocus on the questions at hand. As they began to discuss the questions and planning how they would respond, Leah read one of the questions and blurted out, “How am I going to use this big idea in the future? I don’t know! I don’t like science.” Leah, as described earlier, was resisting the activity—in essence erecting another brick wall. This time, rather than explicitly falling back
on her predetermined career trajectory and how science would not serve her well on this path, she simply stated, “I don’t like science.” In general, however, once the groups started working on their posters, they worked on their posters with enthusiasm although they were challenged by the questions themselves and asked clarifying questions.

![Figure 5.2. Responding to Questions](image)

**Artifacts and Reflections.** There were five groups, and each group created a poster. Three of the posters (see Figure 5.2) fell into a distinct category, that of Responding to Questions. Posters from these three student groups answered the questions literally and on a rather surface level, although these students did respond to each and every guiding question provided to them. Two of these posters were entirely written out with words (except for a depiction of a DNA strand on one, and the use of the starfish as a graphic organizer on the other), utilizing the language of the questions themselves to fill out space. The third was almost entirely drawn, providing pictorial responses to each question.
The responses centered on the idea that the structure of DNA and RNA influences
traits, especially in future generations. It is interesting to note that two of the
groups (on the left and right of Figure 5.2), when asked about how they might be
able to use the big idea they identified in the future they indicated that they would
be able to teach it to others, while the other group (in the center of Figure 5.2),
comprised of Margarid, Leah, and Amanda, noted they would be able to
“determin[e] what our offspring might have for characteristics.”

It should also be noted that this middle group’s response to the question
regarding the curriculum materials and activities themselves reflected Leah’s
overtly stated dislike of science that was apparently shared—or at least
represented—by the group as a whole. Margarid did most of the writing and
wording herself in consultation with the other two girls in the group. She wrote,
“The readings and activities about DNA and RNA did not make learning
interesting or fun, neither did we learn anything surprising. Biology is not a major
I wish to contribute throughout my life career.” This response effectively shut the
door on any kind of input by knowledge of biology on their identities and ways of
being in the world; in Leah’s conception, a thick brick wall was thrown up to block
out any kind of interest in understanding biology and allowing that understanding
to influence their life courses.
Figure 5.3. Using DNA and RNA to recreate extinct animals.

The other two posters were each categories unto themselves. These student groups did not answer each of Klafki’s questions directly. Both groups drew pictures and drew upon both a sense of humor and creativity they did not leverage during typical classroom interactions and expressions of what they know. One of the groups decided they would draw a poster depicting how an understanding of DNA and RNA could be used to recreate long extinct animals such as dinosaurs and woolly mammoths (Figure 5.3). There was not a great deal of detail about how such a feat would be accomplished (nor was it covered in class or in their biology textbook). However, this was a different use of the understanding of DNA and RNA than expressed by the other groups although not particularly plausible. It was an attempt, however, to concretize and make sense of the concepts of DNA and RNA in a creative and humorous manner. Much of the poster depicted a future in which stick figures would be able to keep dangerous and extinct animals
as pets. A scientist, however, was drawn in holding a beaker and wearing a lab coat and glasses with the label “scientist finding DNA sequence & recreating it!” This showed, from a content perspective, that this group’s understanding was that all that was necessary to “recreate” extinct animals was their full DNA sequence.

Figure 5.4. A poster representing content.

The final group similarly drew a poster which did not answer all of Klafki’s guiding questions but reflected a sense of humor, illustrating the differences between “jeans” and “genes” as the big idea (see Figure 5.4). This group was comprised of Kimberly, Spencer, and Leslie; Spencer and Leslie drew themselves in the picture as heads in a test tube, and while a “scientist” figure was drawn—with yellow skin, glasses, spiky hair, a lab coat, and a cross on a necklace—Kimberly made sure to indicate that this did not represent her, and, although obscured for privacy reasons, wrote her name in a corner. A biology book was also drawn in the center of the poster, although none of the elements on the poster were particularly linked together in a cohesive manner. The play on words between “jeans” and “genes” is reflective of efforts to connect to everyday experience in science. It is
important to keep this kind of “presentation of content” poster in mind, as it became the dominant form of drawing posters in the second round of the activity several weeks later. It is this convergence towards the “presentation of content” which is significant, and will be discussed further below.

**The Second Gallery Walk: The Emergence of Collective Practice**

Later on during the research period, the students engaged in the Gallery Walk activity again. Ms. Stoneham assigned the students to new groups. Having experienced it already, they quickly started work on responding to the questions on the worksheet and creating their posters.

**Social Interactions.** As the work progressed, I noticed—contrary to the first time they created posters—the students were working independently rather than as a group to answer the questions on the worksheet. While some of the groups then came back together to discuss their responses on the worksheet, Debra, in her group, began drawing figures on her poster and had to ask her other group members to participate. The class worked in relative silence with very little chatter in the room. This may be in part due to other factors, especially the weather, which was gray and rainy, and even Ms. Stoneham noted that the class seemed “sleepy” that day.
Artifacts and Reflections. In addition to this shift from collaborative to individual responses, I reminded the class twice during the activity to make sure to write out at the very least their understanding of the Big Idea of the unit on heredity and genetics. I felt compelled to do this as the students in their groups were tending to draw presentations of content, rather than responses to Klafki’s questions (see Figure 5.5). As noted above, the students drew their posters so that they represented content, in greater detail than the first set of posters, although these presentations were still lacking in terms of depth of understanding. In
addition, the students did not incorporate the degree of creativity and humor they exhibited in the first round of posters.

This shift towards the presentation of content was noticed by the students too. Ms. Stoneham led a discussion about the similarities among this second round of posters; students noted the fairly ubiquitous presence of Punnett Squares as well as the presence of people, mostly in terms of representations of two parents and one child. While the students did for the most part create posters which basically represented content, Ms. Stoneham was able to help students connect this more broadly through the classroom discussion:

Juana: Physically, like everybody had like the same big idea about science.
Ms. Stoneham: And what was the same, this basic big idea out there?
Juana: Just like, like how we can see, like find out probability and stuff like that.
Ms. Stoneham: How we can see this. What else? What is another way of putting the big idea? I see heredity in a lot of them.
Rosa: How traits are passed on.
Ms. Stoneham: How traits are passed down. So the big idea from this unit is really how traits are passed down. Anything else that was in there? You said people, you said Punnett squares?
Beryl: Just like most of them had the same words from class.
Ms. Stoneham: Most of them had words, dominant, recessive. So what do we call those when we were talking about them in class?
Beryl: Vocab.
Ms. Stoneham: Vocabulary. Vocabulary was important for this one. Um, so most of you are saying that you see, when you look at it, like there’s a lot of parents with children, is that what you’re saying too? So we’re seeing how we got them. What do you think of this unit, how does it tie into the DNA unit that we did? How does DNA and genetics tie in?
Debra: It shows like how these traits can be passed on down one or two generations.
Ms. Stoneham: DNA and heredity can show how these can be passed on down from generation to generation.

Ms. Stoneham assisted the class in clarifying the collective big idea to “...how traits are passed down” so that it resonated with both the objectives of the unit and the posted state-mandated standards. Beryl also noted that many of the posters reflected the vocabulary words highlighted in class, and Ms. Stoneham reinforced the idea that appropriate vocabulary knowledge was “...important for this one.”

Lastly, Ms. Stoneham guided the students to consider the connections between the current unit (heredity) and the previous unit (the structure and function of DNA) in order to elicit a sense of how one unit builds on another. Debra’s response, “It shows like how these traits can be passed on down one or two generations,” was validated by Ms. Stoneham.

As the conversation seemed to be winding down, I asked a follow-up question in terms of the differences, rather than the similarities, between the posters. There was general agreement among the students that there was more in common between the posters than different. I then asked the students to consider the range of differences between the first set of posters they drew compared to the second:

Researcher: One of the things that I noticed is that there was a lot more that was the same than different compared to the last one.
Ms. Stoneham: Yeah, last time we had a lot of differences.
Debra: Mm hmm.
Ms. Stoneham: This time, a lot more similarities. So, what does that tell you?
Researcher: Actually, what are you telling us?
Ms. Stoneham: Yeah, what are you telling me, that last time you had a lot of differences, this time you had a lot of similarities.
Margarid: We all had the same idea about genetics.
Ms. Stoneham: So you all had the same idea, as you’re saying about genetics. Much more uniformity about genetics.
Margarid: Because it’s more detailed than the DNA ones.
Ms. Stoneham: It’s more detailed than DNA.
Margarid: It’s more detailed, so it’s more specific than the DNA ones.
Ms. Stoneham: It’s more specific than DNA. DNA was more general.
Margarid: Yeah.

It is first worth noting that I intentionally redirected Ms. Stoneham’s question in order place the responsibility of both analyzing and creating the posters on the students. At the time, I felt that it was important to remind the students that they themselves drew the posters to connect them back to their own creations and to imbue them with a sense of ownership for their responses. Margarid responded by noting that “[w]e all had the same idea about genetics,” that the students in the class shared an understanding about the unit as a whole. Margarid also noted that not only was there “[m]uch more uniformity about genetics” (in Ms. Stoneham’s words), but the students’ posters also tended to be more “detailed” and “specific” than the previous set of posters.

Asking a further follow up question, I asked the students what they thought of the fact that there were more similarities the second time around, and whether
this was a positive or negative development. Margarid also provided responses to this question as well:

Researcher: So do you think it’s a good thing or a bad thing, that there’s more similarities than differences this time?
[telephone rings and Ms. Stoneham has short conversation on the telephone]
Ms. Stoneham: So, your question was?
Researcher: What do you think about the fact that there’s more similarities than differences this time around?
Margarid: I think it’s kind of a good thing because it means that we’re all on the same page in terms of what we’re learning.
Teacher: Good thing you’re all on the same page, ’cause last time you were all over more.
Margarid: Not that they were all the same pictures, but we all had the same ideas.
Teacher: Now you’re more uniform.

This uniformity did allow for a more detail and in-depth discussion after the activity itself, but it raises the question as to whether a shared and convergent understanding must be reached only by jettisoning the creativity and humor evident in the first round of posters, allowing more of the students’ private selves and meanings to show through more clearly.

Playing the Game: The Emergence of Shared Practices. The changes in posters over the course of the enactments of these two activities, while providing insight into the understandings of students in science and the way they see different ideas in science relating to one another, raises more questions. As the posters moved from a diverse array of different kinds of representations to a fairly uniform set of depictions of science content, this seems to indicate that Ms.
Stoneham and the students figured out a way to develop a set of tacit criteria for what one of these posters are “supposed to” look like. These tacit criteria are based on an understanding of what is expected within the school and science classroom contexts. It was as if students were responding to a traditional assessment item in drawings rather than providing a representation of linked understandings of science ideas. In addition, the activity was designed to foster bridge building between students’ past histories, projected futures, and present learning. Recognizing students’ aversion to cognitively moving forward and backward in time from the rank order activity of potential influences, this activity did not seem successful fostering that process, especially when the enactment of this activity resulted in summaries of current learning.

This activity was intended to support the liberal and renewal humanistic pathways; neither one ended up being particularly successfully represented as the activity was actually carried out. One idea to remember concerning this activity is that it was enacted at the level of ideas and concepts rather than practices and identities. This points to the idea that since so much of schooling is predicated on the manipulation of concepts, ideas, and facts—or, in the terms of figured worlds, such practices and discourses are highly valued—that such activities would most easily be viewed within the context of a conventional science curriculum activity.

Question then arises about what this says about any “intervention” in the face of the structures of schooling. Once the novelty wears off, do interesting and
new activities get subsumed into existing practices of schooling? How can relationships be made between “activities,” a real sense of complexities in science, and a deep understanding of science ideas? The next activity to be discussed, a role play, helps to explore some of these questions.

**The Role Play and the Unfolding Complexities and Meanings of Science**

The students—as well as Ms. Stoneham and myself, for that matter—engaged in a role play activity in which they took on different roles concerning the building of a fictional dog genetics research center in Cotstead. The topic stems from a video that Ms. Stoneham showed to the class about genetics and dogs. As noted earlier, the analysis and report of this activity is done in a time-based manner as the meanings around science learning emerged through sustained discourse, moving from a view of science as instrumental and simple to a view of science as complex and occasionally problematic.

This movement through discourse is the significant frame of this activity. By moving towards a more complex and problematic view of science, students had a greater opportunity to find and bring meanings to science learning. They were also afforded the opportunity to experiment with a number of roles and identities. Some of these identities were squarely within the domains of science, although many others drew upon science in their everyday enactment. This provided students the opportunity to experience the ways that science permeated social roles not traditionally associated with science. The experience also provided
students the opportunity to see that scientists do indeed need to interact with and
gain approval from the public and do not operate entirely separate from the social
sphere.

**Introducing and Framing the Activity.** Both Ms. Stoneham and the
students were quite excited about the prospect of engaging in a role play in science
class. Cotstead High School has a strong performing arts program, and Ms.
Stoneham once told me that the performing artists in the school are held in the
same regard as the star athletes. In order to prepare for the role play, which in
context was a town hall discussion around the proposed building of a dog genetics
research facility, the class watched a the National Geographic video *Science of
Dogs* (*Science of Dogs*, 2007). I had written in my field notes from the day:

> The students all seemed really psyched (I even heard a few "yes!"
whispers with fist pumps) about the idea of a role play. In addition,
the video seemed to really capture the interest of a few students who
didn't necessarily seem to be particularly interested in science in
general. One of these students even wanted to borrow the video.

The video is a National Geographic video on how human breeding of
dogs have impacted dogs as individuals but also how this has led to
 genetic disorders in dogs, not just really useful canines....

The teacher paused the video a handful of times in order to explain
and clarify some of the science and procedures which were at play, as
the video was largely about the end result. The students largely—
but not exclusively—welcomed these clarifications.
The video served as a trigger for not only the activity the following day, but also for
discussion around the nature of genetics, pets, and the relationships between
science and ethics. Concerning the video itself, I wrote:

The video used the term “eugenics” several times, or selective
breeding of a population in order to improve the breed, which has a
rather sinister connotation and feel for me, although I don't think it
does for the students.

In discussion with Ms. Stoneham after class, we both agreed that we weren't sure
that the students knew what the term “eugenics” meant, and did not pick up on
the “rather sinister connotation” that eugenics carries. This lack of connection
would have made some of the points made in the video less poignant and less
contentious.

Without noticing the occasional ethically ambiguous overtones, the video
could easily have been viewed as a documentary heralding the unequivocal
triumph of science over genetic shortcomings. Some of this was present in the
class discussion following the video when Juana asked a question about why
people continue to breed dogs such as pugs and bulldogs when they have
congenital features which interfere with their breathing:

Ms. Stoneham: Why do you think if they have a dog, and they still
    have this problem, why do you think they continue?
Ruby: To find one that doesn’t.
Ms. Stoneham: To find one that doesn’t. And why us? Like, do they
    keep doing it to fix the problem, to try and eradicate it, right?
Ruby: Because they like them.
Ms. Stoneham: Because they like them! And that’s one of the
    biggest ones. Because people like them. And you’ll have
people that absolutely are fanatical about their breed. And they want to continue it. You saw the dog, the Briard. They were over-bred, and what happened to them? They bred blindness.

Gabriel: They fixed it.
Ms. Stoneham: Well, they fixed it through a scientific procedure.

The teacher rephrased the question, and Ruby’s response, “to find one that doesn’t,” put forth the idea that breeding in such cases in order to find a genetic response to the problem. Both Ruby and Ms. Stoneham brought in the idea that certain dogs are bred in the first place “because people like them,” a decidedly non-scientific preference. Gabriel brought back the idea of science as a way to easily “fix” problems even though the problem was brought about by science.

The conversation continued, and while Gabriel had introduced a certain degree of certitude in terms of science having “fixed” the blindness problem in Briard dogs, he also introduced a wrinkle of complexity:

Ms. Stoneham: Yes. Now, then, but then what happened with the blind dog, they used, what, scientific knowledge, of our knowledge of a virus, and they did what.
Gabriel: They fixed their eyes.
Ms. Stoneham: They corrected the problem. Right? So what can we learn then about that, what did that lady say? What did she say about that we can learn from the dogs?
Gabriel: How to help him.
Ms. Stoneham: How to help him. Because if we can correct it in dogs, do you think people who are blind, what ramification will that have, how can we extend that?
Juana: Like maybe we can test it on humans.
Ms. Stoneham: Right, could we test it on humans and see if it worked? And if it works in dogs, it might work in us?
Gabriel: Yeah, it probably won’t work in all, like, blindness. Like if there was a person who had the same problem as that dog
where the vitamin A wasn’t working, and in another person where like maybe the eye like is not working.

Ms. Stoneham: Right. But could we eventually maybe figure out what’s causing that and then use the same techniques? So we can use similar techniques on a dog. Is it better to experiment on a dog than it is to experiment on a human?

Class: [General agreement]

Gabriel was noting that while the genetic problem which caused blindness in the Briard dogs was “corrected,” as Ms. Stoneham pointed out, he also pointed out that the fix only applied to a particular form of blindness endemic to the Briard breed (a genetic disorder in which vitamin A was not transformed properly). Up until this point, the view of science was fairly instrumental and simple: science can be applied to “fix” or “correct” problems. However, with the recognition that there are a range to problems, conditions, and phenomena is one area of complexity that came up in class.

The idea that there is a relationship between science and society also emerged in class, despite the efforts of the students to compartmentalize science and science education as something separate from the social and political spheres:

Ms. Stoneham: So, does science, you guys now, is the population dictating things that are going on in science?
Class: [Affirmative nods and mm-hmm]
Ms. Stoneham: Yes. So, what is that? People are dictating what goes on and what we breed, right? So, if, as a community, or as a group, do you have an effect on what happens in science?
Gabriel: Yes.
Ms. Stoneham: Yes. And why?
Gabriel: We’re part of the population.
Ms. Stoneham: Because we’re part of the population. Exactly!
While in retrospect, the idea of a community “dictating what goes on” in science seems like strong language, Ms. Stoneham did broach the idea that those outside of the community of scientists do have an impact on the work and aims of scientists. It is also interesting to note that Ms. Stoneham not only made mention of individuals bringing about change in science, but “...as a community, or as a group...” This inclusion is an important one given the diverse nature of her C-block class and the potential for the cultures and traditions of some students to favor communitarian rather than individualistic values (Seiler & Elmesky, 2007). By bringing in the human and social aspect of science, and the relationships between broader communities and the communities of scientists, the idea of ethics, responsibilities, and morals was given an entry point. The concept of ethics was introduced by Ms. Stoneham by asked a question asking her students to consider compare the value of a human with the value of a dog:

Ms. Stoneham: What makes it OK to work on a dog and not OK to work on a human?
Debra: ‘Cause like you say they don’t have feelings in the beginning of the year.
Ms. Stoneham: Yeah! [laughing]
Rosa: Because humans are like more complex organisms?
Ms. Stoneham: Humans are more complex. Yep. And is there something we don’t want to do? Remember did we read an article before?
Debra: [unknown]
Ms. Stoneham: Do we have an ethical responsibility towards humans to take care of and not, although you might think it’s slightly different from a dog? You remember our story on Emma? And what happened to her, and how we had to make sure that we can’t just, and when they figured out the small
pox and cow pox, that Dr. Jenner, he tried it on the boy, and we asked you why would that probably be not done like that today? Because he was giving him a life threatening, um, condition. So we don't do that to humans. Uh, and we talked about how things have to go through multiple steps.

Debra pointed out that dogs “...don't have feelings...,” positioning humans as different from dogs because of their ability to feel, thus granting human life a greater value. Rosa built on this idea and noted that humans are “...more complex organisms.” She was implying that dogs can serve as a simpler analog to humans from a biological standpoint, so that techniques that worked on dogs would be applicable to biologically more complex humans. Ms. Stoneham, however, reminded the class of “...an ethical responsibility towards humans...,” reminding them of two historical examples from earlier classes. She ended by pointing out that “...things have to go through multiple steps,” that procedures are put in place to safeguard ethical responsibilities in science.

**Social Interactions.** Just as the discussion following the video moved from simplicity to complexity, the role play itself followed a similar pattern. The students were asked to consider the issues surrounding the building of a dog genetics research center in Cotstead. Each student took on a different role and stated their positions. Ms. Stoneham both asked for volunteers and assigned students to a variety of roles at a public hearing of the issues surrounding the dogs genetics research center. Students playing roles sat in a line of desks arranged to face the rest of the class. The remainder of the students in the class sat in desks
facing the “panel” of students playing roles and were expected to play residents of Cotstead.

At first there was broad and general consensus in support of building the dog genetics research center. While support for building the center did not flag as the role play went on, students were challenged in their thinking leading them to consider more complex issues surrounding what seemed to them initially an easy position to take. The move away from a closed and fixed position opened the door for meaning to be found in and brought to the science education experience.

**Scientific Simplicity: Liking or Disliking Dogs.** Each student playing a role had the opportunity to state their opening positions:

Ms. Stoneham: So we’ll start, since the dog is sitting on the furniture there, we’ll start with him first.
Gabriel (Dog): So like, do I say what side I am, if I’m against it or not?
Ms. Stoneham: Yes.
Gabriel (Dog): [unknown] because it doesn’t say.
Ms. Stoneham: That’s right.
Gabriel (Dog): I don’t know, there’s pros and cons. What do I say?
Ms. Stoneham: It’s up to you, Mr. Dog.
Gabriel (Dog): I’ll go with, yeah, it’s a good idea.
Ms. Stoneham: And why.
Gabriel (Dog): Because, um, maybe like, humans know what’s wrong with certain dogs and what’s not, so maybe they won’t have something that’s wrong with a dog breed. So it won’t keep going.
Eduardo (Farmer): Umm....
Ms. Stoneham: Just state who you are first.
Eduardo (Farmer): I’m the farmer [with a twang, resulting in laughter by the class]. Umm, I say it’s a good thing because I want to have dogs that have now that are good for the special work that they do. I guess.
Sam (Security Consultant): I’m the security consultant and I think it’s good idea ‘cause, like the example in the film in the airport, and the smelling of the drugs. I think that would be a good idea, to have dogs sniffing for bombs and drugs.

Up until this point, the three students playing roles were supportive of the research center, and brought in ideas which were raised in the video the day before. Margarid, playing a “townsperson” on the panel, expressed a dissenting posting immediately met with criticism:

Margarid (Townsperson): Um, I’m the townsperson. Am I not supposed to go with it?
Ms. Stoneham: You can do whatever you want. This is your, this is your opinion. Not, you don’t have to, this is your personal opinion. What do you think as the townsperson?
Margarid (Townsperson): Um, I’m, I don’t think it should be built in Cotstead.
Unknown Male Student: Psshhh...
Unknown Male Student 2: Mean!

It should be noted that it was not necessarily Margarid’s position which was criticized, but Margarid herself. She was called “Mean!” by a fellow student, presumably because, as it developed later, it was perceived that if she did not support the research center it meant she did not like dogs. It also emerged through the course of the activity that the research center was seen as an important resource for curing dogs, and potentially humans, mirroring the research around the Briard dogs and finding ways to genetically correct their blindness. The students continued introducing their positions, and Rosa (the Dog Owner), Matt (the Dog Breeder), and Ruby (the Veterinarian) each supported the building of the research center. It was clear that the consensus of the group was in
favor of building the research center, and much of the support for these positions came by reinterpreting statements made by a variety of people in the video. Rosa, the dog owner, and Ruby, the veterinarian, qualified their support by calling for the safety of the animals. These qualified positions did not engender the same kind of negative and critical response as Margarid’s unqualified dissenting position did.

With the knowledge that there was a tacit understanding that the right position was to support the dog research center—at least among the panelists—one would assume that those students playing the role of Cotstead residents in the audience would be reluctant to express dissent and criticize the center. However, Spencer brought up a question regarding who was going to pay for the center. Ruby suggested that a fund raising effort should be undertaken. Eduardo and Gabriel both placed the responsibility for covering the costs of the center on “the town,” without a clear sense of why the town would want to or should contribute funds. Ms. Stoneham carried this argument further, making the link between “the town” and “the taxpayers” for Eduardo and Gabriel. She then encouraged those playing the Cotstead residents to consider the proposal and Debra responded:

Ms. Stoneham: And you [pointing to the “audience”]. You’re going to pay for it?
Debra: No, not me!
Teacher: You have here a concerned citizen who doesn’t want to pay for it.
Matt (Dog Breeder): Then deal with it!
Eduardo (Farmer): You should move to a different town.
[laughter]
Debra: Well, I'll stand up and fight for what I believe in.
Gabriel (Dog): You see what happens?
Unknown Male Student: What, you don’t like dogs?
Margarid (Townsperson): I like dogs, I just don’t think it should be built.
[many students talking at once]

As Ms. Stoneham turned the responsibility over to the audience, Debra expressed that she would not want to pay for it. Similar to the class’s response to Margarid earlier, the students responded in a knee-jerk fashion, admonishing her to “deal with it” or to “move to a different town.” Once again, dissent from supporting the research center was linked to a dislike of dogs. Margarid responded to this even though it was directed at Debra, noting, “I like dogs, I just don’t think it should be built,” in an attempt to decouple the two concepts. There was a general reaction at this point, as many students chimed in to support the building of the research center and to voice their support for dogs in general and their disdain for people who disagreed with them.

Recognizing the “Good” and the Expense of Resources and Time. At this point, Ms. Stoneham noticed that Ruby was attempting to say something, and focused attention on her. Ruby, as veterinarian, proposed an extra fee on the theoretical sale of dogs from the research center, as Ms. Stoneham rephrased it, “...the person buying the dog from the research center, they’ll pay a little bit more” in order to support the ongoing activities of the research center. Debra agreed to this proposal, and also extended it. She proposed that if the research center
“...come[s] up with good results, maybe we could pay them in the future.” So Debra is agreeing to give them money in the future if the outcomes of the center are “good,” or as Ms. Stoneham rephrased it, “worthwhile.” There was not a discussion, however, about what constitutes good or worthwhile results.

Up to this point, the discussion had largely been around economic issues and solutions, particularly around who is going to pay to build and sustain the research center. The opportunity arose to push the discussion to inquire into what would constitute good or worthwhile results of the center, but it is often difficult to catch such a nuanced opening in the moment. In addition, consensus seemed to be arrived at quickly and relatively easily, given the tacit attempt to frame the discussion in terms of liking or disliking dogs. In an attempt to open and sustain the discussion, over the course of the remaining class time I engaged the class and took on a variety of adversarial roles, as I wrote in my field notes for the day:

I ended up taking four different adversarial roles: neighbor who did not want barking 24/7; neighbor whose children were afraid of dogs; neighbor who is a dog breeder who did not want escaped “Frankenstein Monster Dogs” mating with my dogs; and Greenpeace Guy, who just thought it was wrong.

I took on these roles in the order listed above, but occasionally switched back and forth. Beyond the fact that such an approach both entertained and confused the students, leading to a discussion around the distinction between schizophrenia and multiple personality disorder, such adversarial positions also pushed them to consider other points of view and perspectives beyond the dichotomous like-
dislike of dogs or the strictly economic considerations of the situation. They were able to consider their positions in terms of the nature of potential scientific discoveries and ethical responsibilities.

One example arose while I took on the role of the parent with the children who were afraid of dogs (rather than disliking them):

Researcher: OK, so I live on the other side of the [sliding chair over], where the building’s going to be, and, my children are really scared of dogs. And, uh—
Beryl: You really need to move then.
[laughter]
Ruby (Veterinarian): Get a big fence.
Researcher: Well, my family has been in this same house for generations here.
[general class discussion about moving the house]
Researcher: Now hold on a second here, why is science, why is the science research facility, why is that more important than my kids feeling safe?
Gabriel (Dog): Because maybe we’ll find a cure to something your kids might have in the future.

Ruby at first urged me to move or “get a big fence.” Even a comment about my family living in the house for generations engendered a discussion about having the house moved to a new location. These are all, in a sense, quick and relatively easy fixes to the problem as long as a sufficient amount of resources are thrown at the problem. When I asked the class to consider the value of my children’s feelings against the building of the center, Gabriel brought in the idea of the center making a breakthrough to help my children in the future. Not only did Gabriel bring up a response that requires the expense of time, he also brought the
discussion to the realm of scientific discoveries and the potential benefits of research. It was not a matter of liking or disliking dogs, or getting out of the way to make room for the will of the crowd.

**Complexity and Short Term Suffering and Long Term Gain.** Later on, Ruby was able to bring in further complexity, moving the conversation from the scientific to the moral and ethical. At the time, I was playing the role of the “Greenpeace guy”:

Ruby: People experiment on other people to help the general population, so why can’t you experiment on dogs to help the general population?
Researcher: Well, I don’t think anybody should be experimenting on anybody.
Ruby: Well, then there’s going to be no medicine. And if you get sick, then you’re going to die.
[many students talking at once]
Researcher: But that’s the natural thing to do. Everybody dies.
Ruby: Yeah, but wouldn’t you rather live? So what about all those other kids who live on the other side. The dad wouldn’t want to help them?

Ruby first brought in the fact that some sort of experimentation is necessary in order to advance the fields of science and medicine, noting that if experimentation is called to a halt, “...then there’s going to be no medicine. And if you get sick, then you’re going to die.” In response to my comment that “everybody dies,” Ruby engaged the human and moral sides of the argument, by first appealing to the “father” role, asking him to agree in order to benefit his children. While Ruby’s position has not changed, the arguments in favor of building the research center
have become much more complex and layered, considering the implications of the research rather than just relying on a dichotomous like or dislike dogs position. In addition, Ruby, like Gabriel, is highlighting potential—rather than guaranteed—outcomes, asking the dissenting role to support the center as the research may one day benefit his children.

This consideration of potential long term gain continued to emerge through the role play. Indeed, Rosa pointed out that short-term “suffering” may be necessary to realize long term gain:

Ms. Stoneham: Rosa brings up a good point here. The public needs to suffer a little because of your research?
Rosa: Because the dogs are suffering too.
Ms. Stoneham: The dogs are suffering too. So your research is more important than still a few people having some suffering?
[several students voicing agreement and talking at once]
Rosa: It’s like if you’re sick. Maybe you don’t like the medicine, or whatever, you have to suffer drinking it, or whatever. But after, you feel good.
Margarid: And you’re glad kind of that you took it.

Rosa first highlighted the value of alleviating the suffering of dogs. She introduced the idea that dogs matter, not just humans. And then she introduced the idea of delayed gratification, that even if it may be difficult in the present, it will be beneficial in the future.

**The Question of “What If.”** Several other students followed and extended Rosa’s line of reasoning, even as Ms. Stoneham pushed them to think deeply about their position:
Ms. Stoneham: I know what you’re saying. You’re saying that the benefits of your work are going to, your work is going to benefit me at some point in my life?

[several students voicing agreement]

Ms. Stoneham: Can you guarantee me that?

[several students talking at once]

Gabriel: We can’t guarantee you that, but I mean, there’s always that possibility. There’s always that “what if”? What if you get sick, yeah. And we, and you got sick because you didn’t want it.

[many students talking at once]

Margarid: It’s always “what if” kind of.

Ms. Stoneham: So how does science play a role in here though. So you’re saying something science does is better. The benefits outweigh some of the downsides in science? Always?

Juana: You always have to get through something to get something.

Gabriel: You wouldn’t be doing it if the overall outcome wouldn’t help, like, everybody in some way.

Gabriel and Margarid classified Rosa’s line of reasoning as “what if.” The “what if” was not the guarantee that Ms. Stoneham was asking for, but it did set the stage for the research center—at least in the students’ minds—to act in a responsible, ethical, and responsive manner. Ms. Stoneham, however, pushed the students to think critically by considering their tacit agreement with the idea that “…something science does is better.” Gabriel’s response once again positioned the research center to focus on beneficial outcomes for “…everybody in some way.”

**The Move Towards Public Accountability.** Following these points, I asked the class about the center’s accountability to “everybody,” by asking them how they would keep the public informed about their research:
Researcher: So do you have some sort of procedure in place to let the public know for each and every study that you do? Each and every research study that you do?
Gabriel: We'll send out pamphlets.
Ms. Stoneham: So you're going to make sure the public knows what you're doing at all times?
Matt: Yes. We'll send a tweet.
[laughter]

Gabriel and Matt responded by suggesting that the center would publish pamphlets and referring to the social media communication service Twitter. This led Ms. Stoneham to ask the class about making complaints about the research:

Ms. Stoneham: And what if I see what you're doing online and I don't like it.
Matt: Eh, that's too bad.
Gabriel: We'll have a complaints box.
Beryl: You can put it in the suggestions box.

Matt shrugged off any dissenting voices, as did Gabriel and Beryl with their statements around a “complaints box” and “suggestions box” respectively. This further propelled the conversation, however, into the very complex area of considering who decides what constitutes good work and good outcomes. Ms. Stoneham, who was playing the role of the dog, led the conversation:

Ms. Stoneham (Dog): What are you going to be doing to me! What are you going to do to me!
[many students talking at once about their position]
Ms. Stoneham: So, you would terminate me if I came out wrong?
[students voice agreement]
Ms. Stoneham: That's a problem. You don't have a problem with that?
Debra: You kill hamsters.
Ms. Stoneham: Who kills hamsters?
Rosa: Well, mice and rats.
Ms. Stoneham: Scientists kill mice—
[many students voice agreement and name other animals used in experiments]
Ms. Stoneham: Is that an acceptable piece of scientific research? To terminate animals?
Unknown Female Student: Well, people kill babies. They kill the unborn.
Unknown Female Student 2: It’s not a good thing, but sometimes it just happens.
Beryl (Security Consultant): I think that as long as it is safe for people in the end, like, I’m the security consultant, so like the dogs at the airport like checked bags for the well-being of others so they don’t get hurt, and like there’s bombs and everything. So like if there were more dogs like that then it’s like safe for them. But like we need to know like what kind of dogs we are making.

Although I am opting to leave the potentially politically-charged side note regarding “the unborn” aside, the class did delve deeply into morally ambiguous territory, forcing them to consider their positions with even more care and thought. Debra and Rosa noted the examples of using rodents in scientific research, and the rodents are invariably killed. They pointed to this example to support the idea that animals are “terminated” in the course of scientific research. Beryl, playing the role of the security consultant, pointed out that “...as long as it is safe for people in the end...” that the research should go ahead, as such research could potentially make life safer people, as in the example of bomb-sniffing dogs. Yet she mentions a caveat, that “...we need to know like what kind of dogs we are making,” pointing to the idea that an understanding of the genetic work being done—and its outcomes—is necessary to ensure the safety and cooperation of the community.
The conversation continued, as the question of who decides what is good was raised:

Ms. Stoneham: So if you create something that isn’t safe, you’re going to terminate it.
Henry: Safety of the people over the dogs.
Ms. Stoneham: Safety of the people over the safety of the dogs. So it’s all right to sacrifice an animal. Who decides what’s good for the population?
Gabriel: I do!
Unknown Female Student: Everyone.
Ms. Stoneham: Everyone? The people at the research center, or the public? ‘Cause right now the public and you guys are in conflict. We don’t trust you to make the right decisions.
Matt: Fine. Fine!
Ms. Stoneham: So as a public, and you have a research facility that’s going up and you don’t agree with—
Beryl: But you’re a dog!
Ms. Stoneham: I am. Sorry. I don’t want you to kill me.

Henry placed the wellbeing of people over the wellbeing of dogs, creating an ethical heuristic on which to base judgments. Ms. Stoneham then charged her students to consider the heuristic more deeply, but the students did not have a clear answer for Ms. Stoneham. This is a profound question, and the fact that the students even arrived at this point within the context of a science classroom is atypical. This question also serves as a way to open the door to further questions and inquiry from an ethical and moral standpoint in the context of scientific knowledge and practices, potentially leading to informed and reflective decision making and deliberative identity formation in a democratic society infused with science and technology.
Consensus: Addressing Concerns. In the last analysis, the ambiguity and moral complexity in what seemed like a fairly straight-forward position was recognized by the students:

Ms. Stoneham: So what’s like a little bit of a wrap-up here? Something is coming into our town. The concerns, they’ve listened to the concerns. Have the concerns been met?
Gabriel: Not all of them.
[general agreement to Gabriel’s comment]
Ms. Stoneham: So, is there a consensus about do we want a research facility being in our town? Yes or no?
Unknown Male Student: I don’t know what consensus means.
Ms. Stoneham: There is—
Beryl: An agreement.
Ms. Stoneham: An agreement. Everybody thinks we should have it. Have they presented a case, scientific case, have they given us enough evidence and data to say whether it’s a good thing or a bad thing.
Gabriel: No.
Ruby: There needs to be another meeting.
Ms. Stoneham: There needs to be another meeting?
Gabriel: Same time, same place tomorrow?
[several students talking at once]
Researcher: So what do you think the group needs to do?
Ruby: Talk amongst themselves. And have another meeting on their own without the townspeople to like decide what they should do about the concerns.
Researcher: And so what is that they need to present to public? You don’t have to give the answers, but—
Rosa: Like ideas to persuade them that it is a good idea. Or tell them that they saw their concerns.
Gabriel: Well I don’t think all of the concerns are going to be met. But I think, as long as most of the people are okay with that, then, like, the majority.
Margarid: Yeah, the majority.

In response to the question of consensus, Gabriel asserted that there was no consensus, and Ruby said that there needed to be another meeting among the
supporters of the research center in order to better position their argument. Rosa indicated that a successive strategy would include developing “...ideas to persuade them that it is a good idea” and recognizing “...that they saw their concerns.” In the end, however, both Gabriel and Margarid believed that the building of the center could progress even though all concerns aren’t met “...as long as most of the people are okay with that....”

Reflecting on Playing Roles and Complexity in Science. The accuracy of this role play in how a town meeting considers the building of a genetic research center is perhaps immaterial. Over the course of the role play, the conversation came a great distance from dichotomous positions of liking or disliking dogs to one in which students considered the ethical complexity and multiple perspectives which can encompass scientific activity. In reflecting on the activity, several students pointed to these dimensions of science as new to them. Several students also indicated that playing these roles gave them insight into how they themselves might take on these roles in real life (see Table 5.3).
Table 5.3. Sample student reflections on the role play.

<table>
<thead>
<tr>
<th>Question Topic</th>
<th>Student</th>
<th>Reflection</th>
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<tbody>
<tr>
<td>Learning Something New</td>
<td>Sam</td>
<td>Based on the role play, I learned that science is different than what I thought. I noticed that science had lots and lots of obstacles, and you had to battle through in order to achieve and get what you wanted. Obstacles such as arguments w/ the town people made me think this way.</td>
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<td></td>
<td>Ruby</td>
<td>I didn't think science took so much arguing and convincing but it does.</td>
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<tr>
<td></td>
<td>Kimberly</td>
<td>Yes, because I thought it was just doing, but now I realize that you need to discuss a lot with the public.</td>
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<tr>
<td>Comfortable Taking on a Role</td>
<td>Spencer</td>
<td>-Yes, I think it’s a great way to know about animals then just the basic stuff. It will be interesting as a career learning new things about the animals you work with.</td>
</tr>
<tr>
<td></td>
<td>Beryl</td>
<td>Not unless it would cause imediate harm to me or my family. I’m not interested in it.</td>
</tr>
<tr>
<td></td>
<td>Debra</td>
<td>Yes, but perhaps in the future when I become a biologist or a doctor. At this time, I only see myself playing this roles with family and close friends because I Know if I say something, they won't judge me or tease me like in highschool.</td>
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This side of science, fraught with ethical complexity and ambiguity and requiring energy to be expended on convincing others of a position, can open the opportunity for a different kind of “meaning making” than the typical science activity. As Frankl (1966) defined one category of meaning as requiring a response in the face of uncertainty, this role play provided students the opportunity to “practice” in a fairly safe and constrained environment, allowing them to take on roles that they would not have otherwise had the opportunity to adopt. While some of these roles were firmly ensconced in the scientific field, all of the roles
drew upon science without relying on science. This provides a different kind of identity model for students to think about, consider, and bring meaning to science. As this activity drew upon two of the humanistic pathways, liberal and cultural-progressive, it seemed that the cultural-progressive was highly engaging for the students. What was missing was the serious consideration of the scientific disciplines and the scientific epistemology promoted by the liberal pathway. This lack of balance helped to really engage students in the activity and to consider the ethical and moral aspects of science. It also, however, kept them away from a serious consideration of the scientific concepts and processes that were key in the underlying scenario of building a dog genetics center. The penultimate activity in the sequence was also based on the cultural-progressive pathway and also involved students in the role of using science to convince or persuade, without necessarily playing the role of scientist, and is described in the next section.

**Framing Science to Persuade: Practicing Science Communication**

Unlike the role play activity, the activity in which the students engaged in creating a storyboard for a public service announcement is best considered in a case-wise rather than time-bound manner. Once again, this activity tended to allow students to explore the idea of scientific knowledge in-use; how can they position science to accomplish a goal or convince others of a position? As noted in the Methods chapter, the students were asked to develop a storyboard for a public service announcement (PSA) on a topic relating to genetics. Due to the difficulty
that the students encountered in working with the concept of framing—of being deliberate in the “packaging” of their message—I was unable to observe groups engaged in the storyboarding process as much as I would have liked. Instead, I moved around and helped the students to understand and apply the idea of framing when considering persuasion and science.

**Framing and Introducing the Activity.** In order to prepare for the activity, Ms. Stoneham introduced the students to the idea of a science-based PSA by showing the class “Change A Mind About Mental Illness” ([https://www.youtube.com/watch?v=WUaXFJANojQ](https://www.youtube.com/watch?v=WUaXFJANojQ)), a short video seeking to raise awareness about people who suffer from mental illness and the people who care for them (relatives, friends, and loved ones). This topic connected directly with the class topic of the previous day, genetically-linked mental illnesses such as trisomy 21 (Down syndrome). As a result, the students centered their PSA storyboards on this topic.

In addition, beyond simply developing a storyboard, we asked them to consider the “frames” they would apply to their message—how would they package their scientific understandings in order to connect with and convince a large community beyond the classroom. A selection of frames were provided to the students based on the framework developed by Nisbet and Scheufele (2009). As noted above, the student groups’ topics were centered on genetically-linked conditions, especially mental illnesses. The contexts for the storyboards included
a (United States) presidential address aimed at being more considerate to people with Down syndrome, a general ad raising awareness of the nature of Down syndrome, teaching people about genetic disorders in general, and an advertisement to raise funds for a free genetic disorders clinic for the homeless.

**Figure 5.6.** Distribution of frames reportedly employed by individual students.

**Artifacts and Reflections.** Even though they found the concept of framing difficult, the students reported that they drew from the entire spectrum of available frames. Figure 5.6 provides a chart of how individual students reported their use of frames in their group projects, as the individuals occasionally did not report using the same frames as their fellow students in their group. By far, the most widely utilized frames were Social Progress and Morality, pointing to the notion that the students were fairly idealistic in their attempts to convince others and saw these idealistic frames as effective ways to get their messages across. Public Accountability/Governance was listed next, although often used in a way to indicate strong governance reinforcing students’ strong idealism. Economic
Development and Scientific/Technical Uncertainty were listed least frequently.

These frames were also relatively complex and abstract, but the omission of these frames could also be reflective of the fairly focused topics and contexts of raising awareness around genetic disorders.

The storyboards themselves with students’ comments from the reflection sheets can be found in Table 13. These artifacts strengthen the idea that the students were fairly idealistic in their approaches and goals. For example, the group of Beryl, Juana, and Sam provided a script of the Presidential Address:

Hello, I am President Beryl Ryan. I would like to inform you of people with Down syndrome and the difficulties they go through, in order to understand that they deserve to be treated equally. It’s already hard enough for them to fit in and feel respected in other people’s eyes. To be fair and polite, let’s treat them as if they’re our friends, not enemies.

Influenced by the mental illness video of the day before, they were calling for people to understand people with Down syndrome and to treat them with respect, “…as if they’re our friends, not enemies.” The group of Leah, Margarid, and Ruby similarly created an advertisement around Down syndrome awareness, and even went further than the simply the storyboard and created a PowerPoint presentation with a voiceover track. The group asked the audience to consider what they think of “when you see someone with Down syndrome,” and then continued on to depict individuals with Down syndrome as people with feelings and family members.
For the most part, what the storyboards portrayed in terms of attempting to convince others of a progressive and idealistic worldview, they largely lacked in terms of “science content.” Gabriel told me that he and his group conducted research on the topics in which they were interested, namely the genetic component of particular conditions such as ADHD. This research can be seen in the use of statistics of prevalence of these conditions. I asked Ms. Stoneham of this scarcity of what many would consider the hard content of science. She replied to me, “It doesn’t bother me at all, because they are engaging with science.”

<table>
<thead>
<tr>
<th>Group</th>
<th>Storyboard Summary</th>
<th>Frames</th>
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</table>
| Beryl, Juana, Sam | This group created a storyboard for a televised address by the President of the United States, to be played by Beryl. The group saw the President as using her post as a bully pulpit to raise awareness and to encourage people to treat people with Down syndrome with respect. | Social Progress and Morality: “IMPROVING quality of life or solution to problems.”  
Public Accountability/Governance: “informing people about research.” |
<p>| Debra, Henry, Matt | This group created a storyboard for a presentation for their peers at Cotstead High School. The presentation would be on teaching their fellow students about DNA and the relationships between genetics and disease. | Social Progress: “...achieving the good of helping people with disabilities.” |</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Storyboard Summary</th>
<th>Frames</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eduardo, Kimberly, Rosa</td>
<td>This group created a storyboard of an advertisement to raise money for a fictional free clinic which focuses on genetic disorders among the poor and homeless, who may not be able to receive treatment elsewhere.</td>
<td>Economic Development: “need to come up with a budget on how much money we could spend on equipment.” Morality: No explanation.</td>
</tr>
<tr>
<td>Gabriel, Spencer, Unknown Student</td>
<td>This group created a storyboard of an advertisement seeking to raise awareness of the genetic components of a variety of disorders, including mental disorders and attention deficit-hyperactivity disorder (ADHD). In addition to awareness, the group wanted to encourage genetic testing in order to receive the appropriate treatment.</td>
<td>Social Progress and Scientific/Technical Uncertainty: No explanation.</td>
</tr>
<tr>
<td>Leah, Margarid, Ruby</td>
<td>This group created a storyboard for an advertisement to raise awareness about Down syndrome. The storyboard asked the audience to consider what they think of “when you see someone with Down syndrome,” and then guides them to think of people with Down syndrome as people with feelings and family members.</td>
<td>Social Progress, Morality, Public Accountability/Governance: “make quality of life better in the community.”</td>
</tr>
</tbody>
</table>

Table 5.4. Student storyboards and quotations from reflections. Images of the actual storyboards themselves can be found in Appendix L.
The avoidance of depicting science content by the student groups in the storyboards may have been influenced by the activity itself as well. Juana, in fact, responded to the question on the reflection sheet on missing frames with,

Another frame that might be useful in talking about science with people in my community would be Scientific because it tells you the truth & no opinions just truth so that could make people be more interested.

Juana was seeking a way to frame the message in the way that scientific information is typically contextualized in textbooks, as fact and as truth. This connects back to the instrumental sense of science conveyed by the students in the role play, that science can be used to fix problems through its objective “truth.” The sense of truth combined with the sense of idealism portrayed could lead to a potent entry point for discussion around science with the students. This approach, however, would need a great deal of deliberation to ensure that the discussion does not lose the subtlety necessary when dealing with science and science topics.

Another approach to a “scientific” frame, however, may be the introduction of scientific argumentation (Berland & Reiser, 2009; Driver et al., 2000; Duschl & Osborne, 2002) as the frame which scientists use to communicate with one another. So, rather than encouraging the use of “science as irrefutable facts,” reinforcing the “black box” nature of science (Latour, 1999), the rhetorical devices of argumentation can be introduced as a way to encourage the liberal pathway’s
emphasis on a social and evolving view of science in the public sphere, building on and extending the successful cultural-progressive aspects of the activity.

Several students credited this activity with changing their perspectives on science. Although several students indicated, like with reflections on each of the activities, that they didn’t see science differently, several students indicated they did. This change was significant in the second enactment of the Drawing Science in Action activity. Juana wrote on her reflection sheet, “...I saw ‘doing science’ as only gaining knowledge and it’s not. However it is but it also is about helping and I didn’t think that.” Similarly, Leah wrote, “I thought science was just done in a lab, but this exercise made me come to realise [sic] that they also use marketing tools and advertisement to educate the public.” Sam, however, noted the lack of science content, as he wrote, “I noticed it doesn’t have to be very scientific to reach out to people.” This highlights the importance of connecting “engaging” activities such as this storyboarding activity with rigorous expectations around the content and concepts of science learning.

**Redrawing Science: A Reprisal of Meaning, Activity, and the Field**

Moving from private meanings to public activities in the classroom, considering the analysis of interactions and artifacts thematically, chronologically, and case-wise, the question arises if these meanings in and around the field of science has changed for the students over the course of the research. In order to enquire into this question, the students engaged in the Drawing Science activity a
second time. This time around some of the challenges to the activity, particularly Gabriel’s public protests, did not occur. While a number of themes from the first activity did recur, there were some subtle yet striking differences between drawings for some individuals, namely Kimberly and Debra. In addition, an entirely new category of drawings by Juana and Rosa emerged, highlighting the ways that science can be leveraged for the public good.

![Representative drawings of themes in the second activity carried over from the first.](image)

**Figure 5.7.** Representative drawings of themes in the second activity carried over from the first.

**Consistent Themes, Unintended Consequences, and Conceptual Changes.** A number of themes carried over from when the students originally engaged in the activity the first time. For example, there were representations of Science as Collection, Science as Activity, and Science as Nature (see Figure 5.7). There was an updating of the content that students drew in their representations (such as the Punnett Square in the drawing on the left of Figure 5.7, and the expansion of hereditary characteristics such as eye- and hair-color in the drawing on the right). For the most part, however, the drawings did not exhibit a great
deal of change in terms of demarcating the field of science (with some exceptions, as described below).

Some subtle changes, however, did manifest themselves leading to some interesting differences between the beginning of the research period and the end. Kimberly, for example, drew the picture on the left of Figure 5.8 in the first activity and the picture on the right in the second activity about a month later. Both representations can be categorized as Science as Activity. Both drawings also display a dual context: outside in nature and inside, presumably in a laboratory. In the outside half of the context, grass, clouds and a tree can be seen, and even a squirrel makes an appearance in both drawings. In the laboratory half of the context, Kimberly drew in a lab bench and at least a graduated beaker. In the second drawing, there is no person outside like she drew in the first drawing. The word “Knowledge,” which unified the two contexts in the first drawing, is also
missing in the second drawing, as well as the proclamations by the people in the first drawing of “LIFE!” and “Chemicals.” Lastly, the person inside the laboratory in the later drawing (presumably female) is wearing a lab coat and protective gloves while the person inside the laboratory in earlier drawing (presumably male) is wearing neither.

These differences highlight a number of important interpretive distinctions between the two drawings. First of all, there is no longer a human presence in nature, so the outside context of science presumably happens by observing from afar rather than by experience as intimated by the first drawing. Secondly, as time progressed from Ms. Stoneham’s insistence that science is “gaining knowledge,” the idea of knowledge as a unifying theme apparently became less important to Kimberly. Relatedly, she felt it important to describe the materials and objects of study in the first drawing, but not in the second. Of course, there are a number of factors which may have influenced Kimberly’s decision on this particular omission (e.g., she may have felt pressed for time the second time while she did not the first), but these are important distinctions nonetheless. Lastly, despite Ms. Stoneham’s best efforts to stem the idea that science requires a lab coat, Kimberly added one in the second drawing whereas there were no lab coats in the first drawing. This is a significant and unexpected consequence where, rather than depicting “normal” people doing science, a “typical” perspective on the field of science became more entrenched. This is counterbalanced, however, by the
retention of the female figure. While there is research to suggest that the “typical” scientist is male (Matthews, 1996), Kimberly’s “typical” scientist is female, moving the female figure from the outside world of nature to the inside world of the lab.

**Figure 5.9.** Debra’s first (left) and second (right) drawings of Science in Action.

Debra’s drawings also exhibited a number of changes from her first drawing on the left of Figure 5.9 to her second drawing on the right. Her first drawing was an example of the Gaining Knowledge category, with bubbles of science content and concepts entering a person’s head through inward-facing arrows. Her second drawing was much more complex, and difficult to categorize using the themes developed through the first enactment of the activity. The main figure in her second drawing was herself, unlike her first. Illustrated through the conventional comic strip thought-bubbles, she is thinking about five different aspects of science.

The first aspect of science Debra’s illustrated double is thinking about is the concept of evolution. Debra had earlier highlighted evolution as one of the main
organizing principles of biology. The second aspect is a laboratory investigation, replete with different colored substances in beakers and containers. A faceless person is holding one of the beakers and a magnifying glass is centered on some letters. The third aspect Debra drew was two people experiencing nature, with trees, flowers, and animals. There is a bucket or container with a handle, which may indicate that the people are collecting something from the outdoors. The fourth aspect is a depiction of a pile of books, one of them propped up displaying its contents (DNA and RNA), as well as a laptop computer presumably displaying the Animal Planet and Discovery channel websites. Lastly, Debra drew a person in a bed being attended to by a health care worker, as well as a range of medical paraphernalia. She also drew a red cross and a caduceus, both symbolic of the medical profession.

While at first glance, one might assume that Debra’s second drawing could be considered an example of Science as Collections, it is actually much more complex, exhibiting a great deal of depth that the typical Science as Collections illustration did not. With the exception of the representation of evolution—which she identified as a core tenant of biology—and the pile of books and the laptop, Debra went beyond drawing a collection of things and ideas to depicting a number of activities and practices of science. She also included a medical scene; medicine was important to her as a career goal to become a midwife, but it was also a representation of science being used in a way with which many people can connect.
and identify. Similarly, her depiction of the books and the laptop showcased not only the specific scientific content knowledge canonized in the books, but also the more publicly-accessible and public-oriented scientific content of Animal Planet and Discovery. Her second drawing not only demonstrated a range of scientific activities but also highlighted a number of functions of science, including understanding the natural world, serving as a repository of these understandings, sharing these understandings publicly, and using these understandings to improve human life.

Scientists Helping and Improving Communities and the World.

Despite the consistency of themes—with subtle changes—a new theme did emerge in students’ drawings. Rosa’s and Juana’s drawings, on the left and right of Figure 5.10 respectively, depicted the idea that science can be used to improve society and make for a better life. This is similar to the public-orientation of science depicted in Debra’s second drawing, although much more direct and less grounded in specific content.
Rosa labeled her drawing “Scientists will help their community so the world will improve!!” She drew a schematic diagram with three figures labeled “Scientists” connected by an arrow labeled “Help” pointing to a group of six figures labeled “Community.” A number of details deserve highlighting. First of all, Rosa positions scientists as members of a larger community. Not everyone is a scientist, but they are members of a larger population, and are oriented towards helping this larger community. Secondly, by helping their community, their work also not only has a positive impact on the community itself but the world at large.

Juana drew similar themes to depict science in action. She wrote in two explanatory sentences: “Doing science can be basically finding out new ways to make this world a better place for Everyone” and “Doing Science can be in Everyday life.” Juana drew in two vignettes to illustrate her point. In the first vignette, two people, a male and a female, are in conversation. The male figure
says, “We need to save energy,” while the female character responds, “I found a
good way to save energy!” Juana drew a light bulb above the female character’s
head. In the second vignette, a figure labeled “President” with a Lincoln-esque
stovepipe hat in front of an American flag says, “We need to find out ways to make
this world a better place to live for Everyone espessially [sic] Disabled people.”
The reference to people with disabilities is apparently an allusion to the subject of
the PSA activity that the students had recently completed.

Juana brought in references to specific social issues that have roots for
understanding—and potential solutions—in science, that of energy conservation
and the life of people with disabilities. In doing so, she brings in a political
dimension as well. Energy conservation is a politically-charged economic and
environmental issue which is at the forefront of the global climate change debate.
She also attributes a charitable personality to a political figure, the President of the
United States, in his speech in favor of using science to improve the lives of
everyone, especially people with disabilities.

These two pictures represented a new category of science in action for these
students, that science can be utilized to improve communities and the world at
large. Rosa positioned scientists as members of a larger community of people and
Juana introduced a political aspect to science in action. These illustrations served
as an indication that these two girls’ sense of what science is and what it can be
used for was expanded.
As a way to understand the fields of science and science education, this drawing activity provided unique and important insights into how meanings are negotiated within a larger context. Especially with Rosa, Juana, and Debra, a field change occurred in terms of how the students represented the actions and activities in science. For each of these students, they represented science in a way that they could relate to it and engage with it. Asking students to draw pictures, rather than write, of what it looks like to do science, rather than what a scientist looks like, provides a holistic perspective experience into students worldviews and meanings around science and science learning.

**Scientific Knowledge, Public and Private Meanings, Activities, and Identities**

Moving deliberately back and forth between private and public meanings, histories and activities, knowledge and hopes and values, is a difficult task for any kind of learning environment. The interviews and sorting task elicited a complex set of histories and values which have bearing on engagement in the classroom. The activities which were grounded deeply in the cultural-progressive humanistic approach to science education did seem to be relatively successful in providing students with opportunities to engage in and explore complex meanings of science and experiment with a variety of identities with and in science. These opportunities did seem to help students understand that science—and by extension, science education—is greater than what they typically encounter in the
science textbook. They did not, however, tend to push the students to think deeply and reflectively about the concepts and content of science, the epistemologies of science, as represented by the liberal humanistic approach to science education.

In addition, this inquiry helped to call attention to the deep values that Ms. Stoneham hopes to imbue to her students, that of becoming self-directed and self-aware learners, agents of change with science, and interesting and thoughtful members of communities on a variety of scales. These ideas did not necessarily come through in her descriptions of her roles as a teacher. In addition, this research helps to highlight the need to make learning not only “authentic” but “meaningful” and “valuable,” in the sense that their learning is able to connect with and expand their understandings of their personal histories, their sense of their life’s trajectories, and their current circumstances and relationships.

Students were able to find chinks in the armor of the textbook “public science” (Holton in Girod, 2001), the overly logical and well-ordered side of science, in which universal laws and discrete facts trump the emotional and exciting process of science in the making. In doing so, while they may not become scientists themselves, they were able to experiment with meanings and identities which included the consideration of scientific understandings in a variety of contexts, from public debates to scientific communication. And in doing so, some students, such as Rosa, Juana, and Debra, saw the “usefulness” of science and
scientific knowledge grow and expand, and they saw the broader scientific endeavor as potentially having a place for them. Kimberly and Leah, however, did not engage in the same way. As noted previously, in order to reach out to and engage Leah, an activity would have to tread with care and connect explicitly with around her set meanings and identity trajectory. The PSA activity did seem to accomplish this task in a sense, as she did note the use of “marketing tools” with science. For Kimberly, an activity may have to honor and meet her desire to not appear “stupid,” while also providing a perturbing experience to dislodge the flattened notion of science learning and school in general.

In the next and final chapter, the Discussion, I will delve into what implications these findings and interpretations around the meanings in and from the fields of science and science education hold for the preparation teachers to engage in science education, the development of the science curriculum and classroom practices, and how we consider the complex relationships between science, science education, and the needs of society at large.
CHAPTER SIX: DISCUSSION

In introducing this research, I sought to address three interrelated problems, one empirically-oriented, one change-oriented, and one design-oriented. I highlighted the empirically-oriented problem by noting the small number of studies framing the science curriculum as an opportunity to facilitate the negotiation of meaning between students and teachers. I also called attention to the idea that in order to begin to transcend the repetitive cycle of reform outlined by Hurd (1997, 2002), we must also listen to and act upon what students say during the active exploration and negotiation of meaning. Lastly, I noted that there is a lack of general guidelines and principles for developing curriculum-based activities to grant students opportunities to sort through and contribute to the meanings of their own learning in science as an important contributor to this process as the design-oriented problem.

In order to orient my research in the exploration of these problems, I asked the overarching question: What are the relationships between meaning and science that surround the science curriculum for students and teachers? I conducted this investigation within a figured worlds framework, allowing for inquiry into the meanings, identities, and worlds as they emerge. In addition, in cooperation with Ms. Stoneham, the teacher, I created a number of classroom activities meant to supplement the existing curriculum to facilitate and foreground dialogue around the meanings and identities potentially engendered by the science curriculum.
I will now provide three general guidelines for curriculum developers and teachers working on creating and collecting materials with which to teach in order to help inform the work around designing and developing a curriculum which is “lived” (Hurd, 1997, 2002). As noted in the introduction to this dissertation, a lived curriculum is a course of learning materials which provides connections with the lifeworld of the student. It should also be mentioned that in the discussion, I refer to “curriculum” as more than one particular commercially or freely available set or package of materials. Instead, I refer to “curriculum” in the broader sense: as the collection of ideas, concepts, and practices that should and are taught; how these ideas are taught and learned through activities and experiences; and the values and identities that are bundled into the curriculum through the decision making process (Kliebard, 1989). Individual curricula, textbooks, and packets of materials contribute to this broader sense of curriculum, but I consider curriculum in its larger sense in this discussion.

In considering these guidelines in relation to the aims of a lived science curriculum, it must also be remembered that such an approach—in conjunction with the humanistic pathways—provides avenues around what Whitehead (1957) refers to as “inert ideas,” static knowledge passed on down the millennia without reference to the present time, place, situation, and people. It is the pathways around these inert ideas in the science curriculum that this research provides
guidance. As such, I provide the “Three C’s” of a lived humanistically-informed science curriculum: complementarity, confirmation, and choice.

**Complementarity**

Niels Bohr (1937) used the term complementarity\(^3\) to describe light as exhibiting characteristics of both wave and particle. Both characteristics are present and observable, yet the combined outcome is greater than either characteristic on its own. Complementarity in terms of curriculum development would involve drawing upon more than one pathway or tradition, keeping their particular affordances alive, but finding points of intersection so that activities or lessons can build off one another. Drawing upon the findings of this research, designing humanistically-grounded lessons and activities in the science curriculum with complementarity in mind would support two intertwined approaches. The first approach is the complementarity of the Humanistic Pathways described in the review of the literature. The second approach would consider the balance of learning and practice.

**Complementarity and the Humanistic Pathways**

Students indicated they valued Ms. Stoneham as a source of information and knowledge about science and the natural world. In reflecting on the PSA activity, students indicated that they would have benefitted from a science or truth-based frame in which to present their message. A humanistically-informed

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3 John Dewey would refer to this concept as compossibility (c.f., Dewey, 1984). I chose Bohr’s term because it seemed more approachable than Dewey’s term.
approach to science curriculum refutes the idea that science is simple fact. However, keeping complementarity in mind when contributing to the science curriculum is one avenue for addressing these findings.

In the review of the literature, I made the argument that a pluralistic approach to the humanistic pathways is necessary for the science curriculum to fully benefit from a humanistically-grounded approach. Beyond simple plurality, curriculum designers should also seek connections between humanistically-informed activities and lessons so that they appropriately build upon and support one another. The task, in other words, is to create opportunities for complementarity across the humanistic pathways. Such an approach would allow curriculum developers to key in to some of the engaging characteristics of the Renewal and Cultural-Progressive pathways, for example, as well as leverage the attention paid to the epistemologies and practices of the disciplines of science.

In reference to the PSA activity, Juana was looking for a way to represent “just truth” (in her own words). Sam also recognized the lack of scientific information in the PSA storyboards created by the class. For the most part, however, the class found the activity to be very engaging and participated enthusiastically, even if they did not delve particularly deeply with the science ideas, concepts, and practices. Ideally, students will be able to engage both enthusiastically and deeply.
When designing humanistically-grounded science curriculum with complementarity in mind, this PSA activity informed by the Cultural-Progressive pathway would be matched with an appropriate complementary activity informed by the Liberal humanistic pathway. As noted earlier, an activity informed by the Liberal pathway which focuses on the practice of scientific argumentation would be an excellent complement for the PSA activity in terms of introducing argumentation as a “frame” by which to communicate scientific information and understanding to scientists and the broader public. By introducing argumentation in the first place, but then contextualizing it as a frame, we also sidestep the call for inert scientific “facts,” providing a living and lived science curriculum.

Considering all three pathways generally, the liberal humanistic pathway helped to shape the idea that teachers and students alike are deliberate learners and interpreters of the world and the domain of science. The renewal humanistic pathway compelled me to consider the ideas of meaning and agency, with students and teachers existing and acting in the world. The cultural-progressive pathway supported the investigation into communities, social justice, and a curricular orientation toward a better world. These three pathways, when considered within a framework of plurality and complementarity, can provide opportunities for teachers and students to engage in exploring the meanings found in and brought to the science curriculum, as well as to experiment with and try out identities involving science.
Complementarity, Learning, and Practice

Both Ms. Stoneham and Gabriel highlighted interesting tensions in the learning process. Ms. Stoneham discussed two different approaches to learning, which I described as savoir and connaître, while Gabriel made a distinction between “learning” and “practice.” As a reminder, Gabriel described “learning” as “knowing more,” similar to Ms. Stoneham’s gaining knowledge, while he described “practice” as “getting better at something.” The claim can reasonably be made that much of the science curriculum is predicated on the idea of “learning,” rather than “practice,” and high-stakes tests often favor the knowledge gained through the savoir-based approach rather than the connaître-based approach.

While some “authentic” approaches to science curriculum (Barab & Duffy, 2000; Barab & Hay, 2001; Roth & Bowen, 1995) do favor connaître as well as the notion of practice, finding complementarity between “learning” and “practice” in science education, and even having a clear understanding of the similarities and differences between the two, is a challenge that is not often addressed in science education. It is possible that the Next Generation Science Frameworks and Standards (National Research Council, 2012) may bring these distinctions to the fore of conversation in science education by calling for a closer connection between the concepts and practices of science. But the distinctions between “learning” and “practice” should neither be taken for granted nor taken lightly. While Gabriel’s distinction between learning and practice may be consistent with
the progressive edge of the Next Generation Science Standards, it should be noted that Ms. Stoneham was making distinctions between two different kinds of “learning,” two different ways of getting to know something.

The contexts and types of activities in which students engaged influenced the kinds of meaning that they found and developed around science. The activities designed for this research project were categorized in the methods chapter of this dissertation. Building on the Gabriel’s concept of distinguishing between learning and practice presented above and connecting it with the notions of meaning and identity, it is possible to re-categorize some of the activities in which the students engaged. The Gallery Walk activity can be considered as leaning towards “learning,” while the Role Play and the Public Service Announcement can be considered as leaning towards “practice.”

Even though the Gallery Walk activity was structured in order to encourage students to stretch their thinking about what they were learning and to provide a structure for them to build bridges between content, past experiences, and future hopes, for the most part the students were “playing with content.” They were working with and expressing the content of the unit they were studying. It is interesting to note that “content” actually means “that which is contained” (Odlyzko, 2001). By considering the science concepts and ideas as “content,” the students were able to “contain” these ideas to the classroom and appeared to treat the Gallery Walk as a “typical” classroom experience. Over the course of the two
enactments, it became more like an assessment of what students know from “learning” in the eyes of both students and the teacher, rather than an opportunity to construct meaning by bridging past, future, and present. This is not entirely surprising given the current zeitgeist of assessment and accountability in education, with its focus on valuing a single kind of quantitatively-measured achievement test (Hargreaves & Shirley, 2009).

The other two activities, the Role Play and the PSA, were more consistent with Gabriel’s idea of practice. As the role play became more complex, breaking down the public façade of science, students were able to develop ideas and questions, find meanings, and bring in a sense of values that were not evident in the beginning of the activity. Even if they were not “vocal” about such insights during the role play itself, it was clear from many of the reflections the students wrote. Even Leah, reticent to acknowledge the utility and applicability of science education, came to connect science with “marketing techniques” in her business-oriented identity trajectory when she worked with her group to construct their PSA. Debra, Juana, and Rosa all came to see science as a viable pathway to make the world a better place, a value of great importance to all three of them. Through these activities, which favored identity-building and meaning over content acquisition, students were able to “practice” and reflect on what their activities.

It is important to note that these successes were not necessarily opportunities to act as a scientist, but instead opportunities to connect with, draw
on, and use science in other arenas and with other identities. As mentioned above, much of the focus in the contemporary science curriculum is on learning or gaining content, although there is certainly a great deal of effort to engage students in authentic scientific practices. The Next Generation Science Standards seem to be aligned with this effort (National Research Council, 2012). This effort is to be commended and supported, and is an important aspect of providing students with a humanistic science education, connecting with the liberal pathway. Such an approach allows students to try on scientist-like identities for size. For students like Debra, who very much want to engage in the science professions as a career and a calling, this type of experience is especially important and rewarding.

However, it is also important to remember the range of students in the classroom and to provide opportunities to try on other kinds of identities which may draw upon science, although not necessarily rely upon it. This connects well to the following passage written by Eisenhart and Finkel (1998):

Schools must give serious attention to the kinds of identities that are implied by school activities. Our cases... suggest that people change, grow, and learn in the image of identities represented as important in an activity. If the activities of school science represent identities that are interesting, believable, and possible for students to achieve (given existing demands and expectations), then there is greater likelihood that students will participate in science activities and pursue science identities (M. A. Eisenhart & Finkel, 1998, p. 240).

Leah is a case and point for this guideline: whenever she felt her personal trajectory disrupted, she would throw up a “brick wall” to existentially protect
herself. However, she recognized the “marketing tools” in relation to science while constructing the Public Service Announcement with her group. In addition, Rosa and Juana were able to connect with science—and finding meaning in the process—in ways they did not expect by recognizing the roles that science has the potential to play in improving the public sphere. These changes largely emerged through opportunities to play out roles of non-scientists within a science context, providing a more meaningful and more opportunities to bring meaning to the science education experience.

So, drawing upon the idea of complementarity, in addition to providing opportunities to engage in authentic science practices, the science curriculum should also provide opportunities to connect science with existing student identities and to allow students to experiment with identities that are not necessarily scientists but do draw on and engage with science. The science curriculum can provide uniquely linked activities that allow students and teachers to engage in learning and practice and identities in and with science.

As intimated above, however, there would need to be a broadening of evaluation tools for teachers to understand students’ science learning. Providing teachers with rubrics and guides for interpreting student performances in some of the activities outlined in this dissertation, such as the Role Play and PSA activities, would be an appropriate next step in this regard to help provide complementarity
of practice and learning and identities in and with science in the science curriculum.

**Confirmation**

Confirmation, as Noddings (1988, 2010) defines the term, is the recognition that students act with the best of intentions, even if their acts fall short of the expectations of ourselves as educators and the expectations of the students themselves. This recognition becomes educative when, “...we [educators] reveal to him an attainable image of himself that is lovelier than that manifested in his present acts” (Noddings, 1984 in Noddings, 1988, p. 224). This recognition and reflection allows students to explore the gap between intrinsic and extrinsic expectations and what it is they actually do in the classroom, but it also compels the educator to treat each student as an individual with a unique personal history, hoped-for trajectory, and set of present circumstances. In addition to confirming the students, however, the science curriculum can also bring a sense of confirmation to the teacher as well. I will discuss his teacher-focused sense of confirmation after the describing the opportunities for providing confirmation for the students in the science curriculum. Lastly, I will discuss the idea of confirmation when applied to the relationship between students and teachers.

\[4\] The gendered language in this passage is maintained in deference to the original text.
Confirmation and the Students

In closely interviewing students such as Debra, Gabriel, Kimberly, and Leah, as well as the in-class activities, I was able to understand a great deal regarding the students as individuals, their relationships with others inside and outside the classroom, and their relationships with education in general and science education in particular. The students’ approaches to science and science class were nuanced and complex, influenced by their backgrounds, experiences, projected futures, sense of self, and sets of meanings and values. In the end, they were working very hard to interpret what Ms. Stoneham was teaching them and to square these teachings with who they are, where they come from, and where they would like to go. In other words, they were striving to make meaning. From a research perspective, this understanding was invaluable in understanding the class as a whole and how it emerged as a figured world.

In a sense, some of the students in Ms. Stoneham’s class were able to find confirmation through the research and curricular activities that were carried out in the classroom. Debra found that despite her discomfort with language and her fears of a potentially apocalyptic future, she was able to better situate herself within the field of science and science education, particularly given her life-long interest in the subject and her plan to become a midwife. Leah was able to recognize the use of “marketing tools” in communicating science to a broader audience despite her insistence that much of what she learned in science class was
not useful. Rosa and Juana found a way in to science by being shown the relationships between science and making the world a better place, a meaningful goal for these two girls. Their relationships with the ideas, concepts, and content of biology and science, at the very least, were confirmed in part by the interview process (especially with Debra and Leah) and by the research and activity structure themselves (especially with Leah, Rosa, and Juana).

At a certain point, many teachers see caring, confirmation, and recognizing the student as a whole person as an important part of their task (Alder, 2002; Rose & Tingley, 2008). When considering the application of confirmation across the adults involved in the educational process, one would assume that curriculum developers see such a task as part of their work as well, although there is no research to support this claim. This would suggest that such educators would welcome the opportunity to engage in such an undertaking given the proper support and structures.

Based on the findings of this research project and the impetus for such a task in the existing literature, I assert that it is important to build structures into the science curriculum which foster and allow for confirmation of students. Activities such as the Drawing Science activity and the pile sort and rank order instruments paired with one-on-one and group-based dialogue seemed to be particularly useful in eliciting confirmation-ready themes. In addition, teachers could also interview students individually with a revised and abridged protocol
based on those found in Appendices C and D. If these opportunities were made explicit by including them purposefully over the course of the science curriculum, educators would be able to gain a great deal of insight into the lives of their students and their relationships with science. In addition to the activities themselves, however, the curriculum would need to include educative materials (Ball & Cohen, 1996; Schneider & Krajcik, 2002) to provide teachers with ways of interpreting and making sense of the information that students provide. Such educative materials could also recommend strategies for providing students with the confirmation that their special cases require.

**Confirmation and the Practice of the Science Teacher**

As noted above, from the original drawings by the students of science in action, students did “borrow” definitions of the field of science from Ms. Stoneham. Most notably they borrowed the idea that science is “gaining knowledge.” In this sense, the notion that students picked up the idea of science as “gaining knowledge” can be seen as a type of explicit, rather than tacit, “companion meaning” (Roberts & Östman, 1998). Companion meanings are those meanings which are passed on uncritically from curriculum or teacher to students.

When examined more closely, however, two complicating issues arise. First, the fact that Ms. Stoneham put an emphasis on science as gaining
knowledge in the first place may be her own interpretation of the research goals and aims of this project. This may be the case even if she defined science as gaining knowledge for her students at the beginning of the year during the first weeks of class which she refers to as “boot camp.” Second, the fact that these students did represent science in this way may have been in fact a very active and deliberate move: it may have more to do with the idea of showing respect for the teacher and what she says than with the blind and passive acceptance of meaning. The idea that passivity and disengagement behaviors in school may actually be deliberate actions has been gaining traction since introduced through the ethnographic study of “the lads” by Willis (1977), blue-collar boys who disengaged in order to register their disapproval of what they saw as the end result of doing well in school: desk jobs. So, in a sense, even when it seems that students are being passive or disengaged, they are interpreting and acting on the educator’s teachings and what they see is expected of them. This is also consistent with the concept of figured worlds, recognizing students’ agency even if in this case the students’ positionality—the balance of power and authority—is greatly contrasted with the positionality of the teacher. With this imbalance of power, the need to listen and to act on what students say becomes an even greater imperative in order to foster this agency and to facilitate this engagement in and with science. To

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5 It should be noted that a loose definition of science as “gaining knowledge” is not inaccurate. The English word “science” comes from the Latin scientia, which does in fact mean “knowledge.”
return to the previous point, without listening and acting on the part of the educators within the system, including teachers and curriculum developers, the status quo is the world which is continuously figured over time in the science classroom (Carlone et al., 2011).

While Ms. Stoneham may have been very clear on a definition of science, her distinction between “science” and “science education” was more complex, fuzzier, and inconsistent. She herself did not necessarily use the terms consistently, sometimes using them interchangeably both in interviews and in class. Again, as a researcher, I asked her to make a distinction between the two concepts and any attempt to do so may have been forced to comply with my questions. This potential for a research-induced artifact should be recognized, but it should also be recognized that Ms. Stoneham expressed her appreciation on being given the opportunity to think through and consider these questions, issues, and meanings. As time progressed while I was there, I was able to see Ms. Stoneham work through some of the inconsistencies she expressed earlier on. In a sense, Ms. Stoneham recast herself as not just a teacher, but also as a learner who was working through some of the deeper questions and meanings of the subject she was teaching. When applied to the teacher, the idea of confirmation may be as simple as recognizing the teacher as a learner.

As such, it is important that teachers be given such opportunities to discuss and consider what it is they are teaching. Ms. Stoneham was given the
opportunity through this research to inquire into her subject, its forms, its opportunities, and its problems. A deep understanding of the field is an important aspect of pedagogical content knowledge (Shulman, 1998) and the craft knowledge of teaching (Grimmett & Mackinnon, 1992). Although she may not have been entirely coherent and consistent in the beginning, especially when considering the relationship between science and science education, over the course of the research she was able to learn and grow from the experience.

It should be recognized that there are many critiques of contemporary teacher training and professional development system either as being too theoretical or as providing teacher-proof lesson plans and scripts (Webster-Wright, 2009). In order to address these concerns, and consistent with contemporary views on teacher learning (Schneider & Plasman, 2011; Webster-Wright, 2009), such enquiries should be done within the context of practice, not divorced from it. Nor will providing teachers with scripts or lesson plans satisfy this call, as such approaches do not value the teacher as a learner. Through a mindful, sustained, and serious exploration of what science means to the teacher herself, she will be better equipped to talk about it with students and to help them grapple with their own meanings of science learning.

The curriculum has the opportunity to provide such points of and structures for reflection in order to help teachers to be mindful of the domain itself and what it means. Building off of the idea of educative curriculum, rather than
just providing more content information, the “Teacher’s Materials” can treat the
teacher as an intellectual and a learner, prompting them to consider, weigh, and
reflect on the shape of the field of science and what it means to them and to their
individual students.

Confirming the Relationships between Students and their Teacher:
Positionality, Agency, and Meaning in Science

It is also important to recognize the idea that students interpret and act on
educators’ teachings in a context in which positionality—inequity of authority—
plays a powerful role. Bringing the concept of confirmation to this relationship
provides further guidelines for designing and considering science curriculum.

Leveraging Positionality to Promote Seeking and Meaning. The first
guideline recognizes and leverages the positionality of the teacher in relation to
her students by asking the question, what if Ms. Stoneham had defined science for
her students as seeking knowledge rather than gaining knowledge? It is possible
that the students would have interpreted this definition differently and would have
begun their own journey through the meanings of science from a qualitatively
different place. This difference of one word also turns several assumptions
grounded in the word “gaining” upside down: seeking is much more of an active
process than gaining, seeking places responsibility on the seeker, and the
outcomes of seeking are largely unknown compared to gaining—or receiving—a
set package of knowledge. Of course, this is not to say that Ms. Stoneham’s
definition of “gaining knowledge” was meant in any way other than to help her students learn; however, recognizing the potent influence of words coming from the teacher is necessary and can be leveraged to propel students on a lifelong journey of inquiry, learning, and meaning-making (B. A. Brown & Ryoo, 2008; Moje et al., 2001; Yore & Treagust, 2006).

**Granting Agency to Students as Interpreters.** Current science education policy exhibits strong “national” and “global competition” overtones (Fensham, 2009; Fraser-Abder et al., 2006). Such overtones provide an impetus and strong backing for schools to produce scientifically-educated students to compete in a global workforce where national dominance in the scientific and technological sectors are often seen as precarious when positioned against the burgeoning intellectual superpowers on other continents. This may make for effective policy-making, and there is certainly a precedence for this jeremiad-infused approach to setting the direction and values inherent within schools in general and the science classroom in particular (Rudolph, 2002).

When examining the findings from this research, students in Ms. Stoneham’s class saw such influences as somewhat influential at best or “imagined” at the worst. The idea of connecting learning science to country or even to getting a job was not at the fore of these students’ set of values. Yet as noted earlier, much of the science curriculum is predicated on this assumption. Of course, working with a different class, particularly an honors biology class, may have told a
completely different story. But if the idea is to construct a science curriculum which is more inclusive, allowing a broader range of students to engage in science and potentially continue to grapple with science as a scientist or as a citizen, this recommendation is paradoxical: rather than further emphasizing these assumptions, capitalize on the students’ roles as interpreters and agents and allow the teacher, within the context of the curriculum, to learn more about their biographies, goals, and questions. Again, this recognition of students as agents and interpreters both authorizes their perspectives (Cook-Sather, 2002) and empowers them academically (McQuillan, 2005). Such a confirmatory, authorizing, and empowering approach would allow students to assert more control and responsibility over their own learning and help to foster a hybrid space (Calabrese Barton & Tan, 2009) within the classroom where what the student brings to learning is both valued and leveraged towards a long-term learning, meaning-making, and identity development trajectory.

By providing these empowering opportunities, the science curriculum would also be opening up the potential “spaces of authoring” (Holland et al., 1998) for students by examining the relationships between science and other realms—such as considering the overlaps between science and communities, especially as evidenced by the role play activity and the PSA activity—students were able to find new ways to connect with science and science learning. Debra, who confided in me that she hoped to become a midwife in her native Brazil, depicted a science in
her second drawing that was much more open and oriented to the public sphere when contrasted with her first drawing. Similarly, Rosa and Juana depicted a science that addressed public problems and helped make the world a better place, a concept absent from their—or anyone’s, for that matter—original drawings. This is consistent with the well-documented notion that an emphasis on the ways that science and the social good intersect is an important aspect of the pathway to ensure inclusion of girls in science education (Brotman & Moore, 2008; Cunningham & Helms, 1998). However, in the interest of equity in science education (c.f., Shakeshaft, 1995), such an approach should not merely be seen as a way to hook girls in to science but as an integral part of the science curriculum for girls and boys, as both are citizens in the making.

By charting the variety of responses to close interviews by the teacher and students, I have shown how the “private lives” of individuals within the classroom has an impact on the way that they engage and interact in the science classroom. This connects with Nespor’s (1997) metaphor of “tangled up in school.” What happens, has happened, and potentially might happen outside the classroom, from a meanings perspective, is very influential in terms of students’ engagement with science. While often in teaching, research, curriculum development, and policy, we tend to focus on the cognitive processes and the subject matter of the classroom, it is necessary to be aware of students’ goals, interests, identities, and to
an extent, insecurities in order to help students develop a meaningful relationship with science.

In other words, as educators we need to ensure the time and opportunity to listen to and learn from students, granting them a voice in their learning trajectories. Input by students into the academic dimension of their school experience is an important step towards student empowerment (McQuillan, 2005). As noted earlier with Leah, a potential strategy would be to recognize and ensure that the science curriculum connects with her current identity and her perceived life trajectory, while with Kimberly a shake-up to consider herself and her meanings in a different light in terms of science may work. With Debra, a safe and collegial environment for her to learn to express her interests and to improve her science language ability would be important, while Gabriel would thrive with opportunities to “practice” and “get better” at science. A science curriculum which is designed with the humanistic approaches to science education in mind has the potential to provide such opportunities for students to connect and engage with science and empower them to take more control over their identities with science.

From a curricular perspective, both complementarity and confirmation are predicated on a third concept: choice. This last concept will be discussed next.

**Choice and the Humanistic Science Curriculum**

The last area of recommendation for the design and development of science curriculum is the idea of choice. From a curriculum design perspective, this is the
fundamental approach to curriculum which undergirds the previous two
guidelines. In recognition of the diversity of meanings, needs, and identities that
students bring to and look for in the science curriculum, the curriculum itself can
provide opportunities for choice by the educator in order to address the needs,
confirm and expand the meanings, and reflect and broaden the identities that can
emerge through a confirmatory pedagogy and complementary curriculum.

Before moving forward, I bring up the etymology of the word *curriculum*. The word itself originally comes from the idea of “stream” or “course,” as in the
course of a river. The word *current* shares this origin. Buber’s notion of
curriculum as “…a selection of the world… lifted out of the purposelessly streaming
education by all things, and is marked off as purpose” (Buber, 1965, p. 89) does not
seem very foreign when placed in this context. This examination of etymology,
then, connotes that in a sense, curriculum should be considered as *fluid*.

This fluidity allows for some choice in terms of readings and activities, and
the identities and meanings that they carry. At particular junctures, the
curriculum can provide the teacher with a choice of activities and readings. For
instance, at a particular juncture a teacher can choose between a reading around
the story of scientist at work in a lab or in the field or a reading around the story of
a citizen drawing on science to make an informed decision. Based on the ideas of
confirmation and complementarity, a teacher—or a student in consultation with
her teacher—can choose between different stories at different times for the class as
a whole or for individual students. For example, as noted earlier, Debra would have benefited greatly by being able to interact and experiment with stories, identities, and meanings dealing directly with science and science-based professions. Leah, on the other hand, would have found stories, identities, and meanings that drew on and utilized science—but the people themselves were not scientists—would have been more engaging and meaningful. However, it is also important to ensure that such choices do not serve to segregate students and reify existing meanings and identities. As such, it is necessary at times to provide readings and activities which stretch students’ sense of identities and meanings in and with science.

**The Three C’s and the Recognition of Time**

In closing the discussion around the Three C’s of a humanistically-grounded science curriculum, I recognize that a consideration of time needs to be made. In addition, Mrs. Stoneham outlined a number of challenging and at times conflicting roles, all taking her time and attention. Where is the time going to come from for teachers and students to engage in a curriculum built on confirmation, complementarity, and choice?

Some of the response comes from Whitehead (1957): “We enunciate two educational commandments, ‘Do not teach too many subjects,’ and again, “What you teach, teach thoroughly” (Whitehead, 1957, p. 2). This idea is supported by the Frameworks which underpin the Next Generation Science Standards (National
Research Council, 2012). By reducing the amount of ideas and concepts that need
to be taught, more time opens up to teach more deeply. The Next Generation
Science Standards will focus on connecting the concepts to scientific practices.
This dissertation also calls for a consideration of focusing on the Three C’s as well.

**Conclusion**

This study provided empirically-based insights into the meanings that are
negotiated within the science classroom community as well as an in-depth
understanding of how activities and structures can help make this process more
explicit. Through these insights, I was able to provide the curriculum
development field with not only a better understanding of how students and
teachers explored meaning in the classroom, but also recommendations and
guidelines for activities and the settings—the time, place, and structure—in which
the activities were embedded. Undertaken to authorize students’ perspectives and
grant students a voice in science education reform efforts, I find that hearing the
meanings students bring to their science learning is important for educators to
consider as science becomes increasingly intertwined with earning a livelihood and
engaging in the practice of citizenship.
REFERENCES


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APPENDICES
Appendix A: Teacher Interview Protocol (Stage 1)

I. Questions about Teaching Science

1. Why do you teach science?
2. What has been your school and career pathway that led you to teach high school science?
3. What goals do you have for the students in your class?
   a. What would it look like when these goals have been met?

II. Questions about Science and Science Education

1. What is science?
2. What is science education?
3. What do you see as the relationship between science generally and biology specifically?
4. Why is learning science important for your students?
5. Why is learning biology important for your students?
6. What would your students say if they were asked why learning science and biology is important?

III. Questions about Science in the Classroom

1. Please walk me through a typical class period: What are you doing? What are your students doing?
2. How do you see your ideas about science and science education playing out in the classroom?
3. How do you teach about the importance of science and biology in the classroom?
   a. What are some examples?

4. What are some of the challenges of teaching science and biology to your students?
   a. What are some examples of these challenges?
   b. Why do you think these challenges arise?
   c. What are ways you address those challenges?

5. What are some of your favorite personal classroom stories of teaching science and biology to your students?
   a. What makes these stories stick out in your mind for you?

6. What have you learned from your students this year?
   a. How have you thought about your teaching or the curriculum based on what you have learned from your students?
   b. What is an example of this thinking from class?

IV. Questions about Science in the Community

1. If you were to sit down with your students’ parents and families, what would you say to them about what their children are learning in your class and why it is important for them to learn this?

V. What questions would you ask of your students’ parents and families?
Appendix B: Teacher Interview Protocol (Stage 3)

I. Reflecting on the Activities

1. What moment or moments during the activities really stuck out for you? Why?

2. What was the value of doing these activities with your students? (currency)
   a. What did the activities provide for your students?
   b. What did the activities provide for you as a teacher?

3. How did these activities help you think about science and science education? (coherence)
   a. For you?
   b. For your students?

4. Has your thinking about science and science education changed after working with your students on these activities? (coherence)
   a. If so, why?
   b. If not, why not?

5. How has working with your students on these activities changed your thinking about what you are capable of in science education? What your students are capable of in science education? In education in general? (agency)
6. What have you learned from working with your students on these activities about what you can do with science? What your students can do with science? (action)

7. What do you think your students would say if asked these questions?

II. Science and Communities

1. What did you learn about your students from the activities?
   a. What have you learned about what your students know about science?
   b. What have you learned about who your students are as people and where they come from?
   c. What have you learned about yourself as a teacher?

2. Have you learned anything about how science and science education relates to other educational disciplines? What about to other aspects of culture and society?

3. If you were to explain these activities to your students’ families and home communities, what would you say? What do you think they would say to you?

4. How do you think your students would respond to these questions?

III. Playing It Forward

1. How can you see your students using what they have learned about genetics and evolution in the future? Can you give examples?
2. How do you think your students’ communities would want them to use what they’ve learned about genetics and evolution?

3. How do you think your students would answer this question?

4. If your students were in charge of class and allowed to structure the class any way they wanted, what changes do you think they would like to see made?
   a. Why do you think they would like to see these changes made?
   b. Do you think the changes would be reasonable and doable?
   c. Of the changes you mentioned, which ones could you see yourself acting on, either this year or at some time in the future?
Appendix C: Student Interview Protocol (Stage 1)

I. Questions about Learning Biology

1. What do you like about learning biology?
   a. What do you find interesting about it?
   b. What are some examples from class?

2. What are some of the things you find challenging and hard about learning biology?
   a. What are some examples from class?

II. Questions about Science and Science Education

1. How does biology class compare to some of the other science classes you have taken in high school and middle school?

2. How does biology class compare with some of the other non-science classes you have taken?

3. What are some of the reasons it is important for you to learn biology?
   a. What are some examples from in- or out-of-class?

4. What would your teacher say if she were asked why it is important to learn biology?

III. Science Education and the Community

1. What language or languages are spoken in your home? Where does your family originally come from?
2. Do you talk to your parents, brothers or sisters, aunts or uncles, or other family members or adults about biology class? If yes, what do you tell them? If no, why not?

3. If you were to ask your parents or guardians why it is important for you to be in school, what would they say to you?

4. If you were to ask your parents or guardians why it is important for you to learn biology, what would they say to you?

5. If you were to tell your parents or guardians why it is important for you to learn biology, what would you say to them?

IV. Stories of the Classroom

1. Please walk me through a typical day in biology class.

2. So far this year, what is the most important thing you have learned in biology class? Why?

3. So far this year, what is your favorite story of something that happened in biology class? Is there something that happened in biology class that really sticks out in your mind? Why?

4. What has your teacher learned from you? What are some examples?
Appendix D: Student Interview Protocol (Stage 3)

I. Reflecting on the Activity Structures

1. Think back to the different activities that we did in class: Poster Session, Gallery Walk, Drawing Science, Role Play, and PSA. Which one was your favorite? Why?

2. Which one was your least favorite? Why?

3. What were some of the moments from the activities that really stuck out in your mind? Why?

4. What was the value of doing these activities? (currency)

5. How did these activities help you think about science? (coherence)

6. How did these activities change your thinking about what you are capable of in science? In school? (agency)

7. What have you learned from these activities about what you can do with science? (action)

8. What do you think your teacher would say if asked these questions?

II. Science and Communities

1. What did you learn about yourself from the activities?

   a. What have you learned about you and what you know about science?

   b. What have you learned about any of your classmates?
c. What have you learned about your teacher and what she thinks of science?

2. Have you learned anything about how science is similar or different than other classes? What about the ways that science relates to society and politics?

3. If you were to explain these activities to your families and home communities, what would you say? What do you think they would say to you?

4. How do you think your teacher would respond to these questions?

III. Playing It Forward

1. Can you see yourself using what you have learned about genetics and evolution in the future?
   
   a. If so, how? Can you give examples?
   
   b. If not, why not?

2. How do you think your teacher would want you to use what you’ve learned about genetics and evolution?

3. How do you think your family would want you to use what you’ve learned about genetics and evolution?

4. If you were in charge of science class, what would you change about the way that science is taught?
a. What are some examples of what that would look like, or of experiences you’ve had in other classes?

b. Why are these changes important? What would they accomplish?
Appendix E: Base Protocol for Gallery Walk Activity

Description

This activity is based on Klafki’s Questions for a Didaktik Analysis, originally intended to provide a framework for teachers as they select materials. This activity provides a translated version of Klafki’s Questions to students, and students are asked to create posters as responses to these questions. This activity takes one full class period.

Aims

This activity seeks to provide students with a structured opportunity to reflect on the topic covered and consider the materials and the topic’s significance both in terms of coherence with what they already knew, how they have grown intellectually, as well as the topic’s currency in terms of what they value and find interesting.

Design Question(s) Addressed

- What is the place of learning science as I live my life?

Humanistic Pathways

1. Liberal
2. Renewal

Design Approaches

3. Reflective
4. Cooperative
5. Exemplary

Materials

1. Newsprint Pad
2. Colored Markers
3. Klafki’s Questions sheet, one for each group of three students
4. Gallery Walk Reflection sheet, one for each student

Procedure

1. Inform your students that they will be discussing the materials they have just been studying for the past two weeks (either Mendelian genetics or evolution), and they will be designing posters to share with each other and with the teacher about what they have learned.

2. Let them know that the overall question to keep in mind is, “What is the place of learning science as I live my life?” Lead a class-wide discussion on what the question means.

3. Divide the class into groups of 2-3 students each (preferably 3). Provide a copy of Klafki’s Questions Sheet for each group and a copy of the Gallery Walk Reflection Sheet for each student.

4. Ask your students to use the questions on the sheet as a guide for making their posters. Let them know that they may create a poster with words and pictures as they see fit.

5. Provide students with time to first discuss how they want to respond to the guiding questions, and then the time to create the posters.

6. Hang the posters around the room. Ask your students to walk around the room and read/look at the posters. They are welcome to take notes on the front or back of the Gallery Walk Reflection Sheet.

7. When they have looked at all the posters, ask them to respond to the reflection questions.

8. Lead a discussion about the posters and the reflection as a whole class. Ask two or three students to summarize what the class as a whole put on the posters. To help guide the discussion, ask these two students what a poster would look like for the entire class. Ask if any students would like to add anything based on the posters.

9. Discuss students’ responses the reflection questions in terms of similarities and differences.
10. Ask students, based on their posters and the discussion, how they would answer the question, “What is the place of learning science as I live my life?”

11. Ask students if there are any outstanding comments or questions.
Klafki’s Questions Sheet

Please use these questions to guide you as you design a poster about what you have learned in science class these past two weeks about [Mendelian genetics/evolution]. You are free to use words and pictures to create a poster as you see fit. Overall, the question to keep in mind is:

“What is the place of learning science as I live my life?”

1. What was the **BIG IDEA** that you learned while studying about [Mendelian genetics/evolution]?

2. How did this **BIG IDEA** relate to something that you already knew?

3. How might you use this **BIG IDEA** in the future?

4. How did the readings and activities about [Mendelian genetics/evolution] convey this **BIG IDEA** to you?

5. How did the readings and activities about [Mendelian genetics/evolution] make the learning interesting and fun? Did you learn anything surprising?
Gallery Walk Reflection Sheet

What are some of the similarities you see across the different posters, especially in terms of the question, “What is the place of learning science as I live my life?”
What are some of the differences?

What are some of the surprising ideas on the different posters? Did you learn anything new?

What are some of the changes you would make to your group’s poster now that you have seen the other posters? Why?

NOTES:
Appendix F: Base Protocol for Drawing Science Activity

Description

This activity asks students to draw what it looks like to do science and then provides students an opportunity to discuss their pictures in groups and as a whole class. This activity takes one full class period.

Aims

This activity is intended to allow students the opportunity to consider what doing science looks like and express it, especially in terms of a personal relationship with science. This activity is also intended to provide the teacher with a sense of where students are coming from.

Design Questions Addressed

- What is the place of learning science as I live my life?
- What is my place in the larger narrative of scientific discoveries and scientific communities?

Humanistic Pathways

1. Cultural-Progressive

Design Approaches

1. Reflective
2. Exemplary
3. Cooperative

Materials

1. Drawing Science Activity Sheet, one for each student
2. Drawing Science Reflection Sheet, one for each student
3. Pencils and/or pens for each student
Procedure

1. Inform your students that they will be completing an activity in which they will be considering what “doing science” looks like.

2. Let them know that the two overall questions to keep in mind are, “What is the place of learning science as I live my life?” and, “What is my place in the larger narrative of scientific discoveries and scientific communities?” Lead a class-wide discussion on what the questions mean. You may wish to call out the following terms from the second question and ask students to discuss the terms individually: narrative, scientific discoveries, scientific communities.

3. Pass out a Drawing Science Activity Sheet to each student and provide students the time to draw their pictures.

4. Make sure to remind your students that they are not being graded on how “good” their pictures look.

5. Once students have had the opportunity to draw their pictures, ask students to complete the first page of the Drawing Science Activity Sheet, which provides an opportunity to reflect on their own drawing.

6. Collect all of the drawings and divide the class into groups of three or four students (three preferred) and randomly distribute the drawings across the groups.

7. Let your students know that they will be examining the pictures and look for patterns in terms of similarities and differences. Ask the groups to examine the pictures and complete the second page of the Drawing Science Activity Sheet.

8. Bring the class back together as whole. Ask the groups to share what they found based on the pictures they examined.

9. Ask a few students to describe what “doing science” looks like based on what the groups have shared. Ask other students to comment or add to the description.

10. Ask students if anyone drew themselves in the picture. Ask students to share why they did or did not.
11. Ask students if there was anything surprising they learned about “doing science” either from drawing their own picture or looking at the pictures of their classmates.

12. Ask students how they would respond to the questions, “What is the place of learning science as I live my life?” and, “What is my place in the larger narrative of scientific discoveries and scientific communities?” based on the drawings they created and examined.

13. Ask students if there are any outstanding comments or questions.
**Drawing Science Activity Sheet**

Draw a picture of what it looks like to do science:

Please keep these questions in mind as you draw your picture:
“What is the place of learning science as I live my life?”

“What is my place in the larger narrative of scientific discoveries and scientific communities?”

**Drawing Science Reflection Sheet**

*[Page 1, to be completed by individual students after completing their picture]*

If there are any people in your picture, who are they? Do they have any specific characteristics (how they look or how they are dressed) that connects to doing science?

Where does your picture take place? Why did you choose this place?

How do the objects and things in your picture that connect to doing science?

What is happening in your picture? How do the actions connect to doing science?

Did you draw yourself in your picture? Why or why not?
What are the similarities and differences in terms of the people in the pictures? How are they dressed? What do they look like? Does it look like they are expressing any emotions?

What are the similarities and differences in terms of where the pictures take place?

What are the similarities and differences in terms of the objects in the pictures?

What are the similarities and differences in terms of what is happening in the pictures? What are people doing? What are objects doing?

Think about the pictures together. Describe what “doing science” looks like.
Appendix G: Base Protocol for Role Play Activity

Description

This activity takes a contemporary or historical issue connected with the topic of study and allows students to play a variety of roles in a particular scenario. This activity takes one-half to one period to complete.

Aims

This activity seeks to demonstrate the variety of issues and personalities involved in the scientific enterprise to help them recognize that science is a social and socially-connected undertaking, allowing space for them to imagine themselves playing roles within the framework of science.

Design Questions Addressed

- What is my place in the larger narrative of scientific discoveries and scientific communities?

Humanistic Pathways

1. Liberal
2. Cultural-Progressive

Design Approaches

1. Simulative
2. Cooperative
3. Exemplary

Materials

1. Role Play Scenario Sheet, one for each student
2. Role Cards
3. Role Play Reflection Sheet, one for each student
4. Props, as necessary and available
Procedure

1. Let your students know that they will be doing a role play about an issue or event that has to do with the topic they are studying.

2. Let them know that the overall question to keep in mind is, “What is my place in the larger narrative of scientific discoveries and scientific communities?” Remind your students of what they had discussed about this question previously, and lead a class-wide discussion on what the questions mean. You may wish to call out the following terms and ask students to discuss the terms individually: narrative, scientific discoveries, scientific communities.

3. Explain the rules of the Role Play to students:
   a. Students must play their role for at least one minute.
   b. After two minutes, they may “tag” a member of the audience to take on their role.
   c. After three minutes, a student in the audience may “tag” a person playing a role to take on their role.
   d. Every five minutes, the students playing roles must “tag” a member of the audience to take on their role.
   e. The teacher may be “tagged.”

4. Hand out the Role Play Scenario Sheets to every student and read aloud as a class. Make connections with the content covered in class as appropriate.

5. Ask for volunteers or hand out Role Cards to students.

6. Allow students to play out the role play, abiding by the rules.

7. You may wish to ask students to play out the role play several times depending on time constraints, adding an additional piece of information about the scenario each time.

8. Hand out and ask students to complete the Role Play Reflection Sheet.

9. Bring the class back as a whole. Ask students to share what they wrote on the Role Play Reflection Sheet.
10. Ask your students if there was anything surprising they learned about the way science is done or how it interacts with other parts of society.

11. Ask your students how they could see themselves filling any of the roles played out.

12. Ask students how they would respond to the overarching question, “What is my place in the larger narrative of scientific discoveries and scientific communities?” based on their experience in the role play.

13. Ask students if there are any outstanding comments or questions.
Role Play Reflection Sheet

What are three things that you learned about how science is done from doing the role play?

1. __________________________________________________________
2. __________________________________________________________
3. __________________________________________________________

What role(s) did you enjoy or feel comfortable playing? Why?

Based on the role play, is doing science different than you thought? Why or why not?

Could you see yourself playing any of the roles in real life? Why or why not?
Appendix H: Base Protocol for Framing PSA Storyboard Activity

Description

This activity provides a framework for students to create storyboards for “Public Service Announcements” (PSAs) around a topic of study in science class. In doing so, students decide how they will “frame” their PSA in order to communicate most effectively with their home communities. This activity will take one to two class periods.

Aims

The intent of this activity is to allow students to consider how to think about and talk about science in a variety of contexts, especially within their home communities. This activity also provides students with a structured way of expressing to the teacher how science relates to their home communities and what is important to them in science.

Design Questions Addressed

- What is the place of science in what my communities expect of me?

Humanistic Pathways

1. Cultural-Progressive

Design Approaches

1. Simulative

2. Cooperative

3. Connective

Materials

1. One Framing Science Sheet for each student

2. Several copies of the Storyboard Sheet for each group of 2-3 students

3. One Framing PSA Sheet for each student
4. Computer and projector

5. Access to demonstration videos (online or video files)

**Procedure**

1. Tell your students that they will be creating a storyboard for a public service announcement (PSA) based on one of the topics covered in class. If necessary, describe what a PSA is (an example can be found at [http://www.youtube.com/watch?v=hClfq7FeVLM](http://www.youtube.com/watch?v=hClfq7FeVLM)).

2. Let them know that the overall question to keep in mind is, “What is the place of science in what my communities expect of me?” Lead a class-wide discussion on the question.

3. Tell students that their audience for their PSA is the people in their community. Ask the students to brainstorm some ideas of how the people in their community may best relate to science content. Write these ideas on the board.

4. Hand out the Framing Science Sheet and explain the concept of framing by reading the introduction on the sheet. Have students read through the frames and ask for questions.

5. As a class, ask students to categorize the ideas they came up with into the frames on the Framing Science Sheet. Ideas may fall into more than one frame.

6. Let your students know that they will be creating a storyboard for their PSA. Show the storyboarding video ([http://www.youtube.com/watch?v=pWPjjoOF1u8](http://www.youtube.com/watch?v=pWPjjoOF1u8)) to illustrate what a storyboard is and how to create one. If time allows, show the Don Quixote example ([http://www.youtube.com/watch?v=2uylRSIXaJM](http://www.youtube.com/watch?v=2uylRSIXaJM)).

7. Divide the class into groups of three to four students. Help the student groups pick topics or provide topic options from which they can choose.

8. Allow students to develop their storyboard. They may use as many Storyboard Sheets as they wish, but they should keep in mind that their PSA should be about 30-60 seconds long if they actually produced the video. Also check in to make sure they are including frames and the reasoning behind why they have chosen their frames.
9. Ask students to complete the Framing PSA Reflection Sheet.

10. Bring the class back together as a whole. Ask each group to briefly share their storyboard and the frames that they used and why.

11. Ask students if there was anything new or surprising that they learned by thinking about science in a different way.

12. Ask students if they could see themselves using these frames or other frames when talking about science with their friends, families, or community members. Write new frames on the board.

13. Ask students how they would respond to the overarching question, “What is the place of science in what my communities expect of me?” based on their experience creating the PSA storyboards. Ask students if there are any outstanding comments or questions.
Framing Science Sheet

When people talk about science in the media, they often “frame” their discussion. Framing means that they talk about it in a certain way to get a point across, besides just the information. Two researchers, Matthew Nisbet and Dietram Scheufele, have come up with the frames most often used to talk about science. They are listed in the table below.

<table>
<thead>
<tr>
<th>Frame</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social Progress</strong></td>
<td>Improving quality of life, or solution to problems, or harmony with nature instead of mastery, “sustainability.”</td>
<td>Use solar or wind energy to reduce the amount of carbon dioxide in the atmosphere.</td>
</tr>
<tr>
<td><strong>Economic Development/Competitiveness</strong></td>
<td>Economic investment, benefits or risks; local, national, or global competitiveness.</td>
<td>Finding ways to use solar or wind energy efficiently will allow us to sell the technology and stay ahead of other countries.</td>
</tr>
<tr>
<td><strong>Morality/Ethics</strong></td>
<td>In terms of right or wrong.</td>
<td>We have a responsibility to our children and our planet to do what is necessary to reduce the amount of carbon dioxide in the atmosphere.</td>
</tr>
<tr>
<td><strong>Scientific/Technical Uncertainty</strong></td>
<td>A matter of expert understanding; what is known vs. unknown; either brings up or undermines experts and authority.</td>
<td>A majority of scientists agree that what we do has an impact on the amount of carbon dioxide in the atmosphere and on the health of our planet.</td>
</tr>
<tr>
<td>Pandora’s Box/ Frankenstein’s Monster/ Runaway Science</td>
<td>Call for precaution in the face of possible impacts or catastrophe.</td>
<td>Using electricity generated by nuclear power plants may reduce the carbon dioxide in the atmosphere, but there are many other dangers associated with nuclear power, such as radiation leaks and radioactive waste.</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Public Accountability/ Governance</td>
<td>Research in the public good or serving private interests.</td>
<td>The government should support alternative energy research so that the research is not held up by oil companies.</td>
</tr>
<tr>
<td>Middle Way/Alternative Path</td>
<td>Finding compromise or a third way around conflicting views or options.</td>
<td>The “cap and trade” idea allows factories to release as much carbon dioxide as they need to as long as they support other the conversion of other factories to release less, or they need to pay for it.</td>
</tr>
</tbody>
</table>

Your job is to create a 30-60 second Public Service Announcement (PSA) based on a particular scientific topic. The PSA should be targeted at a particular audience, the people who live in your community. You will be creating the storyboard for your PSA. You need to decide which frames you will be using, and how you will be using them.

**Topic:**

Importance for the community:
Main ideas to communicate:

Important frames to use (and why):
| Narration/Dialogue: | Scene Description | Framing and Explanation |
Framing PSA Reflection Sheet

What are the frames that you used in your PSA? Why are they important for talking about science with people in your community?

Could you see yourself using these frames when talking about science with people in your community? Why or why not?

What are other frames, or ways of talking, that might be useful in talking about science with people in your community? Why are they useful?

Based on creating the storyboard, is doing science different than you thought? Why or why not?
Appendix I: Vignettes of Science-in-Action

The case can be made that there is some aspect of science in each of the stories on these cards. Please place these cards into groups in such a way that all the stories in any group are similar to each other in some important way and different from those in other groups. You can put the cards into as many groups as you like and put as many stories into each group as you like. If you believe that one or more of the stories do not represent a story of science-in-action, place them in a separate group. I am not looking for a correct answer – it is your views that count.

When you are finished, I would like each of you to tell me the reasons for your sorting and what it is that the stories in each group have in common.

- **Jerry is investigating how the colonists in Massachusetts lived** at the start of the Revolutionary War. He is looking at books written in the past 100 years about life in Massachusetts at the time, as well as reading first-hand accounts in diaries and newspapers from the Revolutionary War period.

- **George is conducting fieldwork in a salt marsh** (a wetland near the beach), looking for evidence of what influences the movement of shrimp through the marsh over the course of the day. He is asking himself if the strongest influence is the tide or the salt concentration in the water and looking for evidence to support one way or the other.
• **Cosmo is painting a detailed painting with oil paints on canvas.** He paints detailed landscapes with mountains, trees and plants, lakes and rivers, clouds, and the sun or the moon. He tries to make his paintings not only as detailed as possible but also as accurate as possible to what he sees before him.

• **Elaine is making a clock** out of parts she has found around the house. She loves to collect springs, gears, magnets, batteries, even paper clips, and fit them together so that they serve some purpose or do some job.

• **Martina is doing an experiment with a particle accelerator,** investigating how atoms collide with one another to cause the transfer of energy between molecules. She finds this work with things she can’t see, but she can measure, to be both fascinating and rewarding.

• **Adrien is working with his community,** organizing them and getting the members of his community to work with government officials to clean up the neighborhood and protect a wooded area. He does so to protect the environment.

• **Sophia is teaching biology** in a classroom at a high school, introducing her students to the important ideas, concepts, and vocabulary of biology. She gives lectures and organizes hands-on activities to give her students a range of experiences.
• **Aisha is examining a patient** who has had a cough for over three weeks. She takes his pulse and blood pressure, listens to his lungs and his heart, looks in his mouth, nose, and ears, and then prescribes a cough suppressant for him to take.

• **Richard is working in a small city where he is learning about the people who live there.** He is investigating how they work together to bring about change in their neighborhoods. He attends and records their meetings, interviews them, and writes pages and pages of notes.

• **Juan is working to improve the sticky part of sticky notes.** He is mixing a number of chemicals together to see if he can make a sticky substance for less money than what is being used currently to make the sticky part of sticky notes.

• **Jordana is writing a computer program** that will provide a way to see patterns from large and complex sets of numbers. Her goal is to write a very fast program as the sets of numbers her program works with are taken from weather stations around the globe. Meteorologists will be able to use her program to make predictions and warn people of big storms.

• **Chander is writing an article for a science journal** about the relationship between smog levels and genetic variation in sugar maple trees. He is making the claim that high smog levels result in higher levels of
genetic variation. He has gathered evidence to support this claim, and is also drawing on past research for his article.

- **Eliot is setting up a bird feeder outside his back door.** As someone who loves to watch and photograph birds, he also keeps track of which species of birds come to feed in his backyard. He keeps a bird identification book on his window sill so that he can quickly compare photos in the book to the birds he sees outside.

- **Adora is keeping leopard geckos** in order to breed them and sell them to pet stores. She maintains half-a-dozen terrariums in her house with many different kinds of geckos. She knows when to put different geckos together, although she also asks the pet stores for information about what kinds of leopard geckos customers prefer.

- **Isabella is taking a walk in her neighborhood** in the warm spring sun. She feels the sun on her face and a gentle breeze at her back. She listens carefully, and through the sound of the cars, she can hear the birds call out to one another. She notices buds are just appearing on the trees, and under her feet she feels her shoes squish slightly in the wet ground.
Appendix J: Aggregate Proximity Matrix and Cluster Optimization Analysis
for Pile Sort

Aggregate proximity matrix for the Stories of Science-in-Action pile sort (n=13):

<table>
<thead>
<tr>
<th>Historical Research</th>
<th>Salt Marsh Fieldwork</th>
<th>Painting Detailed Landscape</th>
<th>Making A Clock</th>
<th>Part Accel. Experiments</th>
<th>Post Accl. Experiments</th>
<th>Community Organizing</th>
<th>Biology Teaching</th>
<th>Examining A Patient</th>
<th>Ethnographic Research</th>
<th>Improving Sticky Notes</th>
<th>Writing Comp. Program</th>
<th>Writing Article</th>
<th>Setting Up Bird Feeder</th>
<th>Breeding Geckos</th>
<th>Taking A Walk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical Research</td>
<td>0.92</td>
<td>0.08</td>
<td>0.31</td>
<td>0.15</td>
<td>0.15</td>
<td>0.46</td>
<td>0.15</td>
<td>0.38</td>
<td>0.15</td>
<td>0.46</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.46</td>
</tr>
<tr>
<td>Salt Marsh Fieldwork</td>
<td>0.08</td>
<td>1.00</td>
<td>0.15</td>
<td>0.15</td>
<td>0.08</td>
<td>0.23</td>
<td>0.08</td>
<td>0.23</td>
<td>0.08</td>
<td>0.38</td>
<td>0.23</td>
<td>0.38</td>
<td>0.38</td>
<td>0.46</td>
<td>0.31</td>
</tr>
<tr>
<td>Painting Detailed Landscape</td>
<td>0.31</td>
<td>0.15</td>
<td>1.00</td>
<td>0.46</td>
<td>0.23</td>
<td>0.08</td>
<td>0.08</td>
<td>0.15</td>
<td>0.31</td>
<td>0.31</td>
<td>0.15</td>
<td>0.31</td>
<td>0.00</td>
<td>0.46</td>
<td>0.31</td>
</tr>
<tr>
<td>Making A Clock</td>
<td>0.15</td>
<td>0.15</td>
<td>0.46</td>
<td>1.00</td>
<td>0.15</td>
<td>0.23</td>
<td>0.08</td>
<td>0.15</td>
<td>0.46</td>
<td>0.46</td>
<td>0.08</td>
<td>0.15</td>
<td>0.08</td>
<td>0.15</td>
<td>0.31</td>
</tr>
<tr>
<td>Particle Accelerator Experiments</td>
<td>0.15</td>
<td>0.62</td>
<td>0.23</td>
<td>0.15</td>
<td>1.00</td>
<td>0.00</td>
<td>0.23</td>
<td>0.00</td>
<td>0.15</td>
<td>0.46</td>
<td>0.31</td>
<td>0.46</td>
<td>0.23</td>
<td>0.23</td>
<td>0.08</td>
</tr>
<tr>
<td>Community Organizing</td>
<td>0.46</td>
<td>0.08</td>
<td>0.08</td>
<td>0.23</td>
<td>0.00</td>
<td>0.92</td>
<td>0.15</td>
<td>0.54</td>
<td>0.00</td>
<td>0.08</td>
<td>0.00</td>
<td>0.31</td>
<td>0.08</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Teaching Biology</td>
<td>0.15</td>
<td>0.23</td>
<td>0.08</td>
<td>0.23</td>
<td>0.15</td>
<td>0.92</td>
<td>0.31</td>
<td>0.08</td>
<td>0.08</td>
<td>0.15</td>
<td>0.23</td>
<td>0.15</td>
<td>0.38</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>Examining A Patient</td>
<td>0.38</td>
<td>0.08</td>
<td>0.08</td>
<td>0.00</td>
<td>0.31</td>
<td>0.31</td>
<td>0.92</td>
<td>0.08</td>
<td>0.08</td>
<td>0.15</td>
<td>0.08</td>
<td>0.08</td>
<td>0.15</td>
<td>0.15</td>
<td>0.31</td>
</tr>
<tr>
<td>Ethnographic Research</td>
<td>0.46</td>
<td>0.23</td>
<td>0.15</td>
<td>0.15</td>
<td>0.08</td>
<td>0.54</td>
<td>0.31</td>
<td>0.08</td>
<td>0.08</td>
<td>0.23</td>
<td>0.15</td>
<td>0.31</td>
<td>0.08</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>Improving Sticky Notes</td>
<td>0.08</td>
<td>0.38</td>
<td>0.31</td>
<td>0.46</td>
<td>0.46</td>
<td>0.00</td>
<td>0.08</td>
<td>0.08</td>
<td>0.31</td>
<td>0.92</td>
<td>0.38</td>
<td>0.31</td>
<td>0.15</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>Writing Computer Program</td>
<td>0.08</td>
<td>0.23</td>
<td>0.31</td>
<td>0.46</td>
<td>0.31</td>
<td>0.08</td>
<td>0.15</td>
<td>0.08</td>
<td>0.23</td>
<td>0.38</td>
<td>1.00</td>
<td>0.46</td>
<td>0.15</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Writing Article</td>
<td>0.08</td>
<td>0.54</td>
<td>0.15</td>
<td>0.34</td>
<td>0.00</td>
<td>0.23</td>
<td>0.08</td>
<td>0.15</td>
<td>0.31</td>
<td>0.46</td>
<td>1.00</td>
<td>0.23</td>
<td>0.31</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Setting Up Bird Feeder</td>
<td>0.31</td>
<td>0.38</td>
<td>0.31</td>
<td>0.23</td>
<td>0.31</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
<td>0.23</td>
<td>0.10</td>
<td>0.46</td>
<td>0.31</td>
<td>0.31</td>
</tr>
<tr>
<td>Breeding Geckos</td>
<td>0.08</td>
<td>0.46</td>
<td>0.00</td>
<td>0.08</td>
<td>0.23</td>
<td>0.08</td>
<td>0.38</td>
<td>0.15</td>
<td>0.08</td>
<td>0.15</td>
<td>0.08</td>
<td>0.31</td>
<td>0.46</td>
<td>0.92</td>
<td>0.23</td>
</tr>
<tr>
<td>Taking A Walk</td>
<td>0.46</td>
<td>0.31</td>
<td>0.46</td>
<td>0.31</td>
<td>0.08</td>
<td>0.46</td>
<td>0.23</td>
<td>0.31</td>
<td>0.38</td>
<td>0.08</td>
<td>0.08</td>
<td>0.15</td>
<td>0.31</td>
<td>0.23</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Cluster optimization analysis results for 2-6 potential clusters, excluding the diagonal values in the aggregate proximity matrix:

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Fit</th>
<th>R-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.484</td>
<td>0.266</td>
</tr>
<tr>
<td>3</td>
<td>0.349</td>
<td>0.424</td>
</tr>
<tr>
<td>4</td>
<td>0.327</td>
<td>0.453</td>
</tr>
<tr>
<td>5</td>
<td>0.337</td>
<td>0.439</td>
</tr>
<tr>
<td>6</td>
<td>0.351</td>
<td>0.421</td>
</tr>
</tbody>
</table>
Appendix K: Potential Influences on Science

Please place these cards in the order of how much of an influence the ideas presented on the cards have on your participation in science class. I am not looking for a correct answer – it is your views that count.

When you are finished, I would like each of you to tell me the reasons for your sorting and how the influences are different so that you placed one before another.

<table>
<thead>
<tr>
<th>My Interests</th>
<th>Getting a Good Job</th>
<th>My Parents</th>
<th>My Friends</th>
<th>My Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>My Community</td>
<td>My Teacher</td>
<td>My School</td>
<td>It's A Required Class</td>
<td>Nature/ Environment</td>
</tr>
<tr>
<td>My Concerns</td>
<td>People Around The World</td>
<td>My Experiences</td>
<td>My Questions</td>
<td>My Hopes</td>
</tr>
</tbody>
</table>
## Appendix L: Images of Storyboards

<table>
<thead>
<tr>
<th>Group</th>
<th>Storyboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beryl, Juana, Sam</td>
<td>Appendix L Storyboard 1</td>
</tr>
</tbody>
</table>

**Scene Description**

The President talking to citizens about the difficulties that people with Down Syndrome have to go through.

**Framing and Explanation**

- Morality: People to know how had it is to have down syndrome.
- Social: People not to discriminate people with down syndrome.
- Empowering quality of life.

**Narration/Dialogue**

- Treat them as if they were normal.
- They have difficult lives already and don't need this extra struggle. If people being mean to them.
- Take all those tips in consideration to be a better person.

Help improve the lives of people with Down Syndrome so they don't have to suffer it's not their fault.

**Debra, Henry, Matt**

### Storyboard Sheet

<table>
<thead>
<tr>
<th>Scene Description</th>
<th>Framing and Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA? DNA is you.</td>
<td>If you understand how you can change your environment you can prevent your offspring from having Down Syndrome.</td>
</tr>
</tbody>
</table>

**Narration/Dialogue**

- DNA? DNA is you.
<table>
<thead>
<tr>
<th>Group</th>
<th>Storyboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eduardo, Kimberly, Rosa</td>
<td>People are coming together to help build the clinic.</td>
</tr>
<tr>
<td></td>
<td>After the clinic is built people come in sad not knowing what to do but</td>
</tr>
<tr>
<td></td>
<td>order to working Olson they're happy.</td>
</tr>
<tr>
<td></td>
<td>If we donate money to this clinic it will make you community come together</td>
</tr>
<tr>
<td></td>
<td>and it will give these families the help that they need.</td>
</tr>
<tr>
<td>Gabriel, Spencer,</td>
<td>Start - Recreation: Jumping, letters appear on black background.</td>
</tr>
<tr>
<td>Unknown Student</td>
<td>Letters organize into: 1 in 25 people have ADHD; then jump to again.</td>
</tr>
<tr>
<td></td>
<td>Person appears and starts discussing.</td>
</tr>
<tr>
<td></td>
<td>After (person says): If you or someone you love has or potentially has a</td>
</tr>
<tr>
<td></td>
<td>mental/ genetic disorder it’s important to...</td>
</tr>
<tr>
<td></td>
<td>Genetic testing can determine your disorders degree, its source and the</td>
</tr>
<tr>
<td></td>
<td>most proper way of treating it. For more information visit <a href="http://www.abc.com">www.abc.com</a>.</td>
</tr>
</tbody>
</table>
Leah, Margarid, Ruby

<table>
<thead>
<tr>
<th>Group</th>
<th>Storyboard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scene Description</td>
</tr>
<tr>
<td></td>
<td>- Back with Down syndrome on no different then anything else</td>
</tr>
<tr>
<td></td>
<td>- Back screen with words seen on it, narrator’s voice floor</td>
</tr>
<tr>
<td></td>
<td>- Back, scene with words seen on it, narrator’s voice floor</td>
</tr>
<tr>
<td></td>
<td>- Back screen with words seen on it, narrator’s voice floor</td>
</tr>
</tbody>
</table>

Narration/Dialogue:
1. What is the first thing you though of when you heard someone with Down syndrome?  
2. But he knew a person with Down syndrome as a of achieving his or her goals.  
3. And he knew a person with Down syndrome as a of achieving his or her goals.  

For more information: ndss.org