8-17-2009

# Factors Affecting Construction of Science Discourse in the Context of an Extracurricular Science and Technology Project

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ACCEPTANCE

This dissertation, FACTORS AFFECTING CONSTRUCTION OF SCIENCE DISCOURSE IN THE CONTEXT OF AN EXTRACURRICULAR SCIENCE AND TECHNOLOGY PROJECT, by HORACE P. WEBB, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

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ABSTRACT

FACTORS AFFECTING CONSTRUCTION OF SCIENCE DISCOURSE IN THE CONTEXT OF AN EXTRACURRICULAR SCIENCE AND TECHNOLOGY PROJECT,
by
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Doing and learning science are social activities that require certain language, activities, and values. Both constitute what Gee (2005) calls Discourses. The language of learning science varies with the learning context (Lemke, 2001,1990). *Science for All Americans* (AAAS, 1990) and *Inquiry and the National Science Education Standards* (NRC, 2000) endorse inquiry science learning. In the United States, most science learning is teacher-centered; inquiry science learning is rare (NRC, 2000). This study focused on 12 high school students from two suburban high schools, their three faculty mentors, and two engineering mentors during an extracurricular robotics activity with FIRST Robotics Competition (FRC). FRC employed student-centered inquiry focus to teach science principles integrating technology.

Research questions were (a) How do science teachers and their students enact Discourses as they teach and learn science? and (b) How does the pedagogical approach of a learning activity facilitate the Discourses that are enacted by students and teachers as they learn and teach science? Using Critical Discourse Analysis (CDA), the study examined participants' language during robotic activities to determine how language used in learning science shaped the learning and vice versa. Data sources included video-recordings of participant language and semi-structured interviews with study participants. Transcribed recordings were coded initially using Gee's (2005) linguistic Building Tasks

as a priori codes. CDA was applied to code transcripts, to construct Discourses enacted by the participants, and to determine how context facilitated their enactment.

Findings indicated that, for the students, FRC facilitated elements of Science Discourse. Wild About Robotics (W.A.R.) team became, through FRC, part of a community similar to scientists' community that promoted knowledge and sound practices, disseminated information, supported research and development and encouraged interaction of its members. The public school science classroom in the U.S. is inimical to inquiry learning because of practices and policies associated with the epistemological stance that spawned the standards and/or testing movement and No Child Left Behind (Baez & Boyles, 2009). The findings of this study provided concrete ideas to accommodate the recommendations by NRC (1996) and NSES (2000) for creating contexts that might lead to inquiry science learning for meaningful student engagement.

# FACTORS AFFECTING CONSTRUCTION OF SCIENCE DISCOURSE IN THE CONTEXT OF AN EXTRACURRICULAR SCIENCE AND TECHNOLOGY PROJECT

by

Horace P. Webb

A Dissertation

Presented in Partial Fulfillment of Requirements for the
Degree of
Doctor of Philosophy
in
Teaching and Learning
in
the Department of Middle-Secondary Education and Instructional Technology
in
the College of Education
Georgia State University

Atlanta, GA
2009

# ACKNOWLEDGMENTS

It is impossible for me to acknowledge everyone that has made a contribution to my arriving at this point in my academic development. I am certain that, as I write this, I am unaware of some contributions that were either so subtle that they did not pierce the self-absorption that characterized my youth, or that I have forgotten them with the passage of time. So, if you read these acknowledgements, and feel that your name should have appeared among those in this list. Please, do not feel slighted because, through your either unrealized or forgotten contributions, you have a right to claim a share credit for the joy, and satisfaction that I find in this accomplishment and in the life of which this accomplishment is but a small part.

Among those that I will list, I must first acknowledge the contribution of my parents, Horace Lafayette Webb and Florence Manci Webb. They are the ones to whom I owe the most for my being who and what I am in relation to this project and the process that produced it. They made my success possible by absolutely demanding that their children complete what they began, and constantly reminding us that things that are of value are generally not easy. They fostered my love of learning, my curiosity and engaged with me in discussions and fostered ways of thinking that promoted the critical sense that is a prominent feature of this work.

Next, I must express my gratitude to my wife, Susan Bowker. Her forbearance has been boundless. Susan's constant and active support through the timely application of gentle encouragement and the occasional demand that I simply stop my complaining and get on with it has been a major contribution to the completion of this project.

I must also thank and acknowledge the Georgia State University community. I have come two GSU during two periods of my life. The first period began in 1983 when I determined that I would be a public school science teacher. It was during this time that I first encountered Dr. Edward Lucy. During this time, Dr. Lucy had a profound effect on forming my sense of what science teaching and education should be. His involvement in my formation as a teacher is the thread that connects this first period within the Georgia State University community with the second period that began in the summer of 2003. Dr. Lucy's influence on me during this second sojourn was no less great than during the first. One of his main contributions was his encouragement to become involved in scholarly life by attending and making presentations to professional meetings, and becoming involved in scholarly dialogue with prominent scholars in my area of interest.

During this second period, I began my doctoral studies. Early on, I encountered Dr. Nayda Hanna. Dr. Hanna's support and guidance during the early part of my doctoral studies was invaluable. I also would be remiss if I did not mention the major contribution that Dr. Rudy Sirochman made to my interest in the role of language in science education and my decision to make language the focus of my doctoral research. It was through the readings that were a part of the seminar that he led that I was first exposed to the works of Jay Lemke, Stephen Toulmin, James Paul Gee and M.A.K. Halliday.

The Georgia State University community is not limited to professors. It also includes the other students who were my classmates and those that came through MSIT before us.  Several of my classmates provided me with moral and emotional support, therapeutic humor, scholarly sounding boards and interpretive guidance through the seemingly Byzantine arcania of the GSU bureaucracy.   These are the calm and sagacious Dr. Amy Slack, the tough and tenacious Dr. Melissa Kinard, the cerebral and sophisticated Jared Rashford and the incandescent Serida Hoy.  A couple of graduates of the MSIT program made valuable contributions to this project.  First, Dr. Wendy Roberts helped to plan my path through my course work, and provided me with unerring advice on the best professors to take for each course.  Dr. Roberts also read most of what I wrote, and provided excellent advice for revisions.  Second, Dr. Warren Bernard provided a good deal of cheerleading and steered me toward important literature that was pertinent to my study.

With Dr. Edward Lucy's encouragement I contacted two prominent scholars in my area of interest.  These scholars were, Dr. Jay L. Lemke, Professor in the School of Education, Department of Educational Studies, at the University of Michigan and Dr. James Paul Gee, Mary Lou Fulton Presidential Professor of Literacy Studies at Arizona State University.  As I began to prepare the review of literature for my dissertation, I contacted   Dr. Lemke and Dr. Gee and was astounded to learn that they were excited that I had read their writing and that they, too, were excited about the research that I proposed.  I was further astounded that they offered suggestions for further reading in preparing my literature review; they offered suggestions about how to refine my research questions, helped me with difficulties in interpreting tough passages from Bakhtin and Wittgenstein and generally encouraged me to soldier on.

Another key contributor to my efforts was Dr. Elizabeth Stow. Dr. Stow is a dear family friend, and was my mother's teaching colleague at Georgia State University during the 1960s. After my mother's death, I called on Dr. Stow, and asked her to take up reading my dissertation drafts. With apologies for a less apprehending mind than she once possessed, Dr. Stow graciously agreed to what must have been a tedious task. When we began, I expected that Dr. Stow would make certain that I stayed clear of grammatical faults, and that I had not written anything overly silly. She did help me with these problems, but she did not stop here. She also discussed with me my research, the theories and philosophy that underpinned it along with the whys and wherefores of discourse analysis and critical theory. Through these discussions, I sharpen my understandings of these areas and my writing became clearer. I am so deeply indebted to the contributions that Dr. Stow made to this dissertation.

I must acknowledge the essential contributions made by the members of W.A.R. who agreed to participate in this study. Without their patience and tolerance, this work would not have been possible. I must also acknowledge the contributions made by the central office of the school system in which the study was conducted, along with the contributions made by the principles of High Schools #1 and High School # 2. Without the contributions of these school administrators, this study would have been impossible.

Finally, I must acknowledge the contributions of my dissertation committee, Doctors Deron Boyles, Lori Elliott; Amy Flint; Stephanie Lindemann and my committee chair, Dr. Geeta Verma. As a group they helped me to produce a work that I could be proud of. All of my committee members were patient and supportive; however, each also made particular contributions to our efforts. Doctors Elliott and Flint brought a

knowledge and appreciation of James Gee's works and his approach to literacy and discourse analysis. Dr. Lindemann brought her background in linguistics and conversation analysis to our efforts, and gently kept me within the bounds of methodological and analytical orthodoxy. Dr. Boyles, more than any professor that I encountered during my doctoral studies, challenged me to critically examine my philosophy of education and my classroom practice. In addition, he was able to make two hours of class pass as if it were but a minute, even after a day of teaching science to high schoolers. As a committee member, Dr. Boyles made certain that my writing was clear and that my approach to my subject was scholarly.

As my committee chair, Dr. Verma seemed able to do all that was needed to move me through this process. She was the perfect combination of cheerleader and taskmaster; of advocate and critic. As an editor, she always provided clear directions that helped me to improve the design, execution and presentation of my study. Without her, I simply would not have finished this work.

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ABBREVIATIONS

| | |
|---|---|
| AAAS | American Association for the Advancement of Science |
| CDA | Critical Discourse Analysis |
| EOCT | End of Course Test |
| FIRST | For Inspiration and Recognition of Science and Technology |
| FRC | FIRST Robotics Challenge |
| GDOE | Georgia Department of Education |
| GHSGT | Georgia High School Graduation Test |
| IRE | Inquiry Response Evaluation |
| NCLB | No Child Left Behind |
| NRC | National Research Council |
| NSES | National Science Education Standards |
| SCI | Sociocultural Influences |
| W.A.R. | Wild About Robotics |
| ZPD | Zone of Proximal Development |

# CHAPTER 1

# INTRODUCTION

This study focused on students and their sponsors who participate in an extracurricular robotics club. The study investigated how the students and their mentors used language in the learning/teaching contexts presented by the activities of a robotics club, and how language reflexively interacted with this context to facilitate the students' and the sponsors' enactment of their situated identities. The study focused on language because it is the tool that humans use to build the realities of their worlds (Dewey, 1920; Gee, 2005, 2004a; Wodak, 2001; Wood, & Kroger, 2000). As such, analysis of language provided a window to the reflexive interactions that these students and their sponsors used to build situated identities as they learned/taught science and technology.

The role of language, and how language is used to shape and reveal the dynamics of the educational process, has long been of interest to thinkers and researchers from diverse disciplines. Through much of the history of education in the western world, the Socratic method, as utilized by Plato in his Dialogues, has been of interest to scholars. The Socratic method, as utilized by Plato, centers on the linguistic practices that Socrates, as teacher, used to frame the subject of the dialogue and used to draw his students into a dialogue that focused on that subject. For example, in the case of *Meno,* it does not seem to matter who the commentator is; much of the analysis of the dialogue centers on Socrates' use of language (Boyles, 1996; Morrell, 2004; Plato, 1984).

There is no more distinguishing feature of the human species than its use of language (Dewey, 1920). So pervasive is our use of language that it is difficult to conceive of a human existence so hermetic as to be devoid of some contact with language. Most of us do not live sequestered lives. In fact, we seek contact with others, and these interactions always include some aspect of language (Dewey, 1920).

While the focus of this study was an extracurricular science learning experience, this is not the typical setting in which most students learn science and teachers teach it. That setting is the science classroom. The primary reason for choosing an extracurricular science-learning program was the hope that it would provide insights into the language used by students and teachers in a pedagogical context that is all too uncommon in public school classrooms in the United States, open student-centered inquiry. The characteristics of open student-centered inquiry and its status in public school science classrooms is made more meaningful by an understanding of the typical state of science teaching and leaning in public school classrooms (Dawes, 2004; Driver, Newton, & Osborne, 2000; Gallas et al., 1996; Goodlad, 1984; Lee, 2001; Lemke, 1990; Mercer, 1996; Mueller, 2002; Rosebery, Warren, & Conant, 1992; Roth & Bowen, 1995; Simplico, 2002).

For most children, school is an important locus of social activity, and linguistic interactions are the very stuff of the school experience (Shuy & Griffin, 1981). As a component of schooling, the science classroom is no different. Here, too, language dominates. Lemke, in his book, *Talking Science: Language, Learning and Values*, writes, "Learning science means learning to *talk* science. It also means learning to use a specialized conceptual language in reading and writing, in reasoning and problem solving, and in guiding practical action in the laboratory and in daily life"(1990, p. 1).

Talk in the science classroom may be viewed as a continuum; at one extreme only the teacher talks; at the other extreme, only students talk. Current science education research has identified the conditions under which values near these extremes exist (Dawes, 2004; Driver, Newton, & Osborne, 2000; Gallas et al., 1996; Goodlad, 1984; Lee, 2001; Lemke, 1990; Mercer, 1996; Mueller, 2002; Rosebery, Warren, & Conant, 1992; Roth & Bowen, 1995; Simplico, 2002). Traditionally, the science classroom has been teacher-centered. When the classroom is teacher-centered, the teacher is the most important speaker in the science classroom (Dawes, 2004; Driver, Newton, & Osborne, 2000; Gallas et al., 1996; Goodlad, 1984; Lee, 2001; Lemke, 1990; Mercer, 1996; Mueller, 2002; Rosebery, Warren, & Conant, 1992; Roth & Bowen, 1995; Simplico, 2002). However, when students have a voice in what goes on in the classroom, when activities center on more than trivial science exercises, students talk more and teachers talk less. This student-centered approach to teaching and learning science is called inquiry.

Research on language in the science classroom reveals that the teacher is the one doing most of the talking and determining what and how it will be talked or written about (Dawes, 2004; Lemke, 1990; Mueller, 2002; Simplico, 2002). Lecture is a common activity in the secondary science classroom. In this transmissive mode of teaching, students do not select the lecture's topic and have little control over how the lecture is publicly played out. Experience on either side of a high school science lecture shows that there are few if any unsolicited questions from students hearing the lecture (Graesser, Person, & Hu, 2002). An extensive study of classroom activities showed that approximately 75% of class time was devoted to teacher talk, while only 5% of class time was used to generate student response; of total class time only 1% was used to elicit open student responses that involved reasoning or opinions from other students (Goodlad, 1984).

When there is questioning in most secondary science classrooms, the format generally employed is what Lemke (1990) calls "triadic dialogue," or what other researchers refer to as Initiation, Response, Evaluation (IRE) (Durham, 1997; Graesser, 2003; Graesser et al., 2002; Jimenez-Aleixandre, Rodriguez, Bugallo, & Duschl, 2000). In triadic dialogue, while there are questions, these are questions chosen by the teacher. Opinions of the IRE format vary. According to Lemke (1990), this activity structure seems to be favored by many teachers because of the control that it allows teachers to exercise over the classroom. Goodlad (1984) writes that practices such as IRE are "designed to keep students passive and under control just at a time when students should be taking charge of their education"(p. 159). Durham (1997) agrees with Lemke (1990) and Goodlad (1984), adding that IRE at best elicits shallow two- or three- word responses, and places students in a strongly subordinate position. Other researchers, notably Dawes (2004), view IRE as a very useful approach that permits teachers to check for understanding, to expose misconceptions, and to scaffold the student's attempts at understanding by providing new linguistic data. Disagreements about IRE notwithstanding, it is clear that as activities in the science classroom become more inquiry-oriented, they become more student-centered and less teacher-centered.

Inquiry activities are a means of empowering students. In inquiry's most open expression, students may become active agents of their education. When inquiry activities are used to teach science, the focus in the classroom shifts from the teacher to the student. Inquiry activities are student-centered because they place, on the student, some or all of the responsibility for selecting the topic of the inquiry, designing the procedure for the inquiry, determining how the results of the inquiry will be evaluated and designing the presentation of the results and conclusions of the inquiry (Dias, 2005; Martin-Hansen, 2002; Roth & Bowen, 1995; Roychoudhury & Roth, 1996). Inquiry requires that students perform many of the activities of scientists (Dias, 2005; Martin-Hansen, 2002; Roth & Bowen, 1995; Roychoudhury & Roth, 1996).

To qualify as inquiry, an activity need not be completely “open”; that is, center entirely on the students. Many authors recognize a continuum of inquiry activities that are by degree more or less student-centered (Dias, 2005; Eick, Balkcom, & Meadows, 2005; Martin-Hansen, 2002; American Association for the Advancement of Sciences, 1990; National Research Council, 2000)**.** In each case, these authors recognize the changes in the roles or responsibilities that teachers and students assume as classroom activities move from lecture to open inquiry. Implicitly or explicitly each author makes reference to the change in the teacher’s role from that of provider or transmitter of knowledge to that of facilitator, or knowledgeable co-learner. As for the students’ roles, these authors note that the responsibility for the nature of the activity, and the construction of individual and group knowledge, is shifted to students. An example of an inquiry learning activity is in Appendix A, and a teacher-centered activity is in Appendix B.

The movement in science education from teacher-centered approaches to student-centered approaches came about as a result of the development of constructivism. Constructivism is a broad term that is associated with the post-modernist reaction to the behaviorism/empiricism that dominated educational research and practice in the first seventy years of the twentieth century (Abdul-El-Khalick & Lederman, 2000). Epistemologically, constructivism holds that science and all other areas of knowledge are social constructs, and, as such, are the products of individual minds that are influenced by personal experiences.

Science teachers know that students have a wide range of experiences before they begin attending school and that, on the basis of these experiences, students construct theories about the way that the world works (Mintzes, Wandersee, & Novak, 2005). Although these theories or prior conceptions may not fall within the bounds of accepted scientific theory, they may serve the student well in his/her day-to-day life. A first step in constructivist science pedagogy centers on determining what prior conceptions of the world the student has constructed (Mintzes et al., 2005). The role of the teacher in the constructivist science classroom is to facilitate construction of knowledge through activities that expose the inadequacies of these prior conceptions, so the student may begin, through inquiry, to construct conceptions of the natural world that fall within the bounds of accepted scientific theory (Mintzes et al., 2005).

While constructivist epistemology is centered on the knowing and shaping of worlds through individual experience, it does not treat the individual as an island. Even radical constructivists, such as von Glasersfeld, who place a strong emphasis on the role of individual experience in constructing realities, acknowledge the prominent role of social interaction as a source of individual experience (Glasersfeld, 1984). Social interaction requires language in some form (Dewey, 1920; Gee, 2005). Since education is situated in the broad social/cultural context, it is not surprising that constructivist educational philosophy and theory centers on the use of language. So strong is this influence that Dewey (1920) attributed the very construction of the individual mind to social interaction through language.

Dewey and, more so, his Russian contemporary, Vygotsky are identified with the stance that is known as Social Constructivism (Mercer et al., 2004; Scott, 1998; Siegler, 1998; Wertsch & Toma 1991). Social constructivists believe that all aspects of culture arise through negotiated meanings that are a result of the use of shared common signs and language situated within the local social, ethnic, political, economic, age and gender context of those that employ them (LeCompte & Schensul, 1999). Both Dewey (1920) and Vygotsky (1981) viewed human culture as the source of knowledge, and viewed language and collaboration with more competent members of the culture as the most important cultural aspects of knowledge construction.

Over time, Vygotsky has become most strongly associated with Social Constructivism. Vygotsky’s elaboration of Social Constructivism with his "general genetic law of cultural development" (Wertsch & Toma 1991, p. 163) is one of his most valuable contributions to learning theory. In his "general genetic law of cultural development" Vygotsky posits that all human cognition begins intermentally, that is, cognition develops first as a result of an individual's contact with some aspect of society. Following this contact, the knowledge is internalized and made intramental through the activity of the individual mind on that experience. The intramentalization of an idea makes that idea an unique construction of the individual mind. Vygotsky called intramentalized knowledge “inner speech” because, even though knowledge was a product of the individual’s interaction with some aspect of culture, knowledge nevertheless retained its contact with its cultural origins (Wertsch & Toma 1991, p. 162) through its association with culturally situated tools and signs. Of these, Vygotsky was most interested in the mediation of cognition by signs, which might include any means used to organize one's own or others' actions. These signs included what Vygotsky called social languages (Wertsch & Toma 1991).

Social Language is a term that Vygotsky lifted from the Russian philosopher and literary critic Bakhtin. By a social language, Bakhtin meant the spoken or written texts of a society or a distinct group within a society (1986). When social languages are joined with the activities, tools and values of a group they become what Gee calls Discourses with a capital "D". Social languages in conjunction with these other cultural factors are the way that we build and declare our identities within social groups.

Gee's (2005) view of language is sociolinguistic. Sociolinguists propose that language is a cultural product, and that a language has no meaning outside of the context of the community of its users. Further, sociolinguists hold that language is never used frivolously; it is always employed for a social purpose. When members of a language community speak, write or use other symbol systems, they do so with certain social functions in mind. Gee refers to these functions through which we form our social realities as "Building Tasks" (2005).

Gee (2001) defines Discourses as any undertaking where the meanings of words, phrases and sentences are situated or where the use and meaning of language is "customized to our actual contexts" (p. 716). By context, Gee (2001) means, "not just the words, deeds, and things that surround our words or deeds, but also our purposes, values, and intended course of action and interaction" (p. 716). Gee continues, saying that

> Discourses always involve language (i.e., they recruit specific social languages), but they also involve more than languages as well. Social

> languages are embedded within Discourses and only have relevance and meaning within them. A Discourse integrates ways of talking, listening, writing, reading, acting, interacting, believing, valuing and feeling (and using various objects, symbols, images, tools and technologies) in the service of enacting meaningful socially situated identities and activities.(p. 19)

On the basis of these criteria, Gee (2005) characterizes science as a Discourse.

Lemke's approach is similar to Gee's, but addresses the scientific undertaking specifically. Lemke also sees science as a social activity that employs specific language in connection with specific activities. More importantly, Lemke (1990) views the "talking" of science as inextricably bound up in the activities of science.

> Learning science means learning to *talk* science. It also means learning to use this specialized conceptual language in reading and writing, in reasoning and problem solving, and in guiding practical action in the laboratory and in daily life. It means learning to communicate in the language of science and act as a member of the community of people who do so. "Talking science" means observing, describing, comparing, classifying, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing, lecturing, and teaching in and through the language of science. (p. 1)

For Lemke, learning science or "talking science" is not something that is done *to the student* but is something that is done *by the student*.

In these longer passages there are lists of activities that each author views as bound to socially situated language. Gee's (2001) list of activities is general and associates Discourse with "ways of talking, listening, writing, reading, acting, interacting, believing, valuing and feeling (and using various objects, symbols, images, tools and technologies) in the service of enacting meaningful socially situated identities and activities" (p. 719). Lemke (1990), on the other hand, writes specifically of science Discourse and produces a list of activities associated with "talking science" that parallel

Gee's more general list of activities. Both authors regard science and science learning as Discourses (personal comments, Gee, 11/5/2005; Lemke, 3/5/2007).

Inquiry affords students the opportunity to use the language of practicing scientists as it is situated in the activities and values of practicing scientists. Learning science through inquiry affords students the opportunity to try on the identity of a scientist and, in so doing, to project their personal identities onto what it means to be a scientist. Comparing the classroom that uses inquiry to learn science with a traditional classroom that does not, Gee (2004b) draws an analogy between a young person taking part in a computer game and one who actually participates first-hand in an experience.

> However active and critical learners can do more than simply carryout the role of playing a virtual scientist in a classroom. They can form a projective identity as well. If learners are to do this, they must come to project their own values and desires onto the virtual identity of "being a scientist of a certain sort" in this classroom. They must as well, come to see this virtual identity as their own project in the making become – an identity that they take on that entails a certain trajectory through time defined by their own values desires choices and goals, as these are rooted in the interface of their real-world identities and the virtual identity …. If learners carry on learning so far as to take on a projective identity, something magic happens – a magic that cannot, in fact, take place in playing a computer game. The learner comes to understand that he or she has the *capacity*, at some level, to take on the virtual identity as a real-world identity. (p. 114)

Gee's (2005) and Lemke's (1990) views of science and science learning as Discourse are significant because they reflect the learning approaches and goals of key education documents such as *Inquiry and the National Science Education Standards* (NRC, 2000) and *Science for All Americans* (AAAS, 1990), that call for students to learn through inquiry what it means to be a scientist. The failure of schools in the United States to abandon teacher-centered pedagogical approaches in science classes in favor of inquiry is a persistent problem that some (Gee, 2004b; Lemke, 1990; Roychoudhury & Roth, 1996) feel is at the heart of our schools' failure to produce the "magic" of which Gee (2004b) writes.

## Statement of the Problem

The focus of this study was how students and teachers use language in learning science. However, more specifically, this study focused on how research into the language that is used in open student-centered inquiry can illuminate the reasons for, and address, the gap that exists between current science knowledge among students in the United States and the stated goals for science knowledge and science learning practices in the policy documents like *Science for All Americans* (AAAS, 1990), *Bench Marks for Science Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 2000). Further, this study has revealed some reasons for, and helps to address, the failure of the current dominant modes of pedagogy to achieve those goals. The policy documents advocate a broad knowledge of science concepts, a working knowledge of scientific practices, an understanding of Nature of Science that includes an understanding of science as a human social undertaking. These same documents state that these aims are achievable through student-centered inquiry pedagogy.

The problems that are responsible for the current state of affairs in science learning are as follows:

1. Currently, science pedagogy is dominated by teacher-centered approaches; teacher talk is dominant. (Dawes, 2004; Driver, Newton, & Osborne, 2000; Lemke, 1990; Wertsch & Toma 1991). The approaches result from teachers' beliefs that knowledge resides in them and can be transmitted only by them (Tobin & McRobbie, 1996); and beliefs that student-centered pedagogy is

inefficient and time-consuming and does not permit complete coverage of curricula-mandated topics or permit proper preparation for high-stakes tests (Geelan, Wildy, Louden, & Wallace, 2004; Tobin & McRobbie, 1996; Wallace & Kang, 2004).

As a result of these teacher beliefs and teacher-centered pedagogy:

2. Students do not engage in Science Discourse. They experience science as a list of facts or conclusions (Roth & Lucas, 1997; Schwartz et al., 2002; Tobin & McRobbie, 1996). They view science as a special empirically-driven enterprise that is totally separate from other human enterprises. A student's knowledge of science exists in isolation from classmates' knowledge of science. Students do not have an opportunity to collaborate and mutually construct knowledge and to understand science as a social product (Lemke, 1990; Rosebery, Warren, & Conant, 1992; Roth & Bowen, 1995; Warren & Rosebery, 1996; Wertsch & Toma 1991)

According to science education literature, current pedagogical practices are dominated by teacher-centered forms that limit the opportunity that students have in constructing their own understanding of science concepts either as individuals or in collaboration with their classmates (Driver et al., 2000 ; Newton, Driver, & Osborne, 1999 ). Students' understanding of scientific knowledge, processes and the nature of science are naïve or wholly lacking (Driver et al.; Jimenez-Aleixandre et al., 2000 ; Klaassen & Lijnse, 1996; Lemke, 1990; Newton et al., 1999 ; Roth & Lucas, 1997).

Researchers have identified dialogic language or discourse as an essential component in acquiring the sort of scientific knowledge identified in the *Science for All Americans* (AAAS, 1990), *Bench Marks for Science Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 2000) (Dawes, 2004; Lemke, 1990; Newton, Driver, & Osborne, 1999). Research has also shown how important discourse is to developing deep understandings of science concepts (Graesser et al., 2002; Roth, 1993; Roth & Bowen, 1995; Roth & Lawless, 2002). Other researchers have investigated how language changes as students' views of science become more sophisticated (Kawasaki, 2004; van Zee, 2000; Roth, 1997; Roth, 1996).

Student talk is only one side of linguistic exchanges that take place in the science classroom. Other researchers have investigated teacher talk or use of linguistic resources. Researchers have investigated how teacher talk affects the social atmosphere of the science classroom and either promotes or attenuates learning (Freeman & Taylor, 2006; Mason, 2001; Mueller, 2002; Ngeow & Kong, 2003; Oh, 2005; Rodrigues & Thompson, 2001; Scott, 1998; Zack, 2002). Still others have highlighted the significance of student-teacher talk in the classroom to learning science (Lemke, 1990); Lemke, 2001; Klaassen, 1996).

## Rationale and Significance of the Study

I selected the topic of this study because of a longstanding interest in how language is used in learning science. However, my interests go beyond linguistic analysis. Because I view learning as socially constructed through language and other semiotic elements that comprise our symbolic culture, my interests extend to how language is used to promote learning through the relationships that exist among students themselves and between students, their teacher and the broader social milieu of which this process is a part. Findings in this area are very useful to practitioners because they serve as a guide to creating contexts in their classrooms that can promote the sorts of language that result in deep understandings of science content and culture.

Much as in studies reported in the literature (Roth & Bowen, 1995; Roychoudhury & Roth, 1996; Salyer, 2000; Warren & Rosebery, 1996), in classes that I have taught I have noticed that, at special times and on rare occasions, students can become completely absorbed in solving a problem. At these times their focus is very different from routine instances where they have been asked to solve a pencil-and-paper example from their text or from a worksheet, or when they are listening to a lecture or viewing a video. If students speak at all during these more routine activities, their talk generally revolves around procedural issues such as due dates, scoring of the assignment, format of assessment, and so forth (Jimenez-Aleixandre et al., 2000). The selection of the study setting was predicated on the belief, which proved correct, that an extracurricular extended science and technology project might provide more opportunities to study this sort of student-and-teacher response to a science learning context.

In the aforementioned special instances, their concerns are centered on "What's going on?". Their talk is frequently in the form of claims or counter-claims about observations or interpretation of observations. There are questions: "I wonder what would happen if…?;" " I wonder how….?;" "Hey! Doesn't the book say that the relationships between A and B should be directly proportional….?;" and "Do you think that….?" Sketches of graphs representing data and diagrams depicting the relationships between various observations are occasionally made. At these times the students are engaged in the sort of behavior that scientists and engineers regularly engage in. The students form a community that exhibits the same sorts of values that communities of scientists exhibit. As with science-in-practice these times are messy, they are contentious, they are time-consuming and, like "real science," they have a magical quality (Jimenez-Aleixandre et al., 2000; Roth & Bowen, 1995; Roth & Lawless, 2002; Roth & Lucas, 1996; Roychoudhury & Roth, 1996; Warren & Rosebery, 1996).

In my classroom, during these times of genuine inquiry, as reported in the literature (Ritchie & Tobin, 2001; Roychoudhury & Roth, 1996), phenomena may be observed that leave me, the teacher, as puzzled as my students. At these times, I cannot fall back on pronouncements about expected results that come from having seen a canned lab exercise performed hundreds of times before. Under these conditions, I become a co-investigator. At these times, my role in the classroom is radically changed. I begin to argue for my interpretation of observations. My talk sounds a lot like my students' talk (Ritchie & Tobin, 2001; Roychoudhury & Roth, 1996). I become a full member of the dialogic process (Driver et al., 2000).

When students have experienced this approach to solving a problem, the conceptual aspect of knowledge that, before, was fragmented or totally absent is more nearly complete (Ritchie & Tobin, 2001; Roth, 1993; Roth & Lucas, 1997; Roychoudhury & Roth, 1996; Warren & Rosebery, 1996). After these experiences, students readily return to this approach for doing inquiry activities and also begin to apply some of the new repertoire to more routine problems that they must solve in the science classroom (Roth & Bowen, 1995; Roychoudhury & Roth, 1996). All too rarely, students are heard to ask a classmate, "Why did you try to work number 23 that way instead of the way that Mr. Webb worked it?" rather than the more frequently heard, "Hey! How do I work number 23?"

My interest is in the language that students and teachers use as they teach and learn science in different pedagogical contexts. I am interested in how, during these times, students use language to enact Discourses. What happens during the rare and wonderful instances that I have observed in my classroom and in others is a Discourse

(Gee, 2001; Lemke, 1990; Roth & Bowen, 1995; Roychoudhury & Roth, 1996). During these times students are "doing science" (Jimenez-Aleixandre et al., 2000 ). But when students do the more routine things in science class, they are enacting another Discourse (Gee, 2001; Lemke, 1990). During these times the students are simply doing the lesson (Jimenez-Aleixandre et al.).

To learn science in the way that is advocated in *Science for All Americans* (AAAS, 1990), *Bench Marks for Science Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 2000), science students need to become participants in Science Discourse. This means that students must not only learn to "talk the talk"; they must also learn to "walk the walk". In other words, learning science must not be about learning just the facts and vocabulary; it must be about becoming a participant in the activities that constitute science and embracing the values of science.

*Teachers' influence on pedagogical context of the science classroom*

The teacher's role in the classroom cannot be ignored. How does the teacher promote "talking science"? How does the teacher promote the development of scientific practices and values among a community of learners that are part of the *Science for All Americans* (AAAS, 1990), *Bench Marks for Science Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 1996) recommendations? The NRC document recommends several approaches.

1. Standard B: Teachers of science guide and **facilitate learning** (NRC, 1996, p. 32).
   a. Strategy: In doing this, teachers **orchestrate discourse** among students about scientific ideas. They require **students to record their work**…and they **promote** many different **forms of communication**. Using a **collaborative group structure**, teachers encourage interdependency. Such group work leads students to recognize the expertise that different members of the group bring to each endeavor and the greater **value of**

**evidence and argument** over personality and style (NRC, 1996, p. 45, excerpted and emphasis added).

2. Standard E: Teachers of science **develop communities of science learners** that reflect the **intellectual rigor of scientific inquiry** and the **attitudes and social values** conducive to science learning.
   a. Strategy: This requires teachers to **nurture collaboration** among students to **foster** the practice of many of the **skills, attitudes, and values that characterize science**. It also depends on **communication** amongst the **community of learners**. The ability to **engage in** the **presentation of evidence**, **reasoned argument**, and **explanation** comes from practice. Teachers **encourage informal discussion** and **structure science activities** so that students **are required to explain** and **justify** their understanding, **argue from data and defend their conclusions**, and **critically assess** and **challenge the scientific explanations of one another** (NRC, 1996, p. 50, emphasis added).

These passages advise the teacher's taking a role in the science classroom to help students to learn science through practices that Lemke (1990) would call "talking science". The role that a teacher chooses to play in the science classroom influences the pedagogical context of the classroom. Firstly, the teacher exerts an influence through the role that he/she takes in selecting activities for the class. Secondly, the teacher shapes the pedagogical context of the classroom in the way that he/she chooses to "teach" the activity.

The first passage from *National Science Education Standards* (NRC, 1996) recognizes the primary role of language in learning science by recommending that teachers "orchestrate *discourse* among students about scientific ideas." This passage also encourages teachers to provide students opportunity to practice being scientists, and to encourage students to adopt values that are typical of the scientific community (Driver et al., 2000 ; Duschl & Osborne, 2002; Gilbert, G. N. & Mulkay, 1984; Toulmin, 1958). The second passage advocates the building of communities of science learners that do the learning of science in much the same way that scientists do science. To this end, the teacher is to nurture collaboration, foster practice of skills, attitudes, values, and encourage certain language practices.

There are numerous studies and theoretical articles in the literature that indicate that a teacher's role in the class or the way that a teacher chooses to teach an activity has a strong influence on the sort of learning that goes on in a science classroom. These studies and articles highlight the importance of teachers' modeling scientific skills, attitudes, values and linguistic practices for their students (Driver et al., 2000 ; Duschl & Osborne, 2002; Lemke, 1990; Roth & Bowen, 1995; Roychoudhury & Roth, 1996). Wegerif and Sams (1994) note that "the voice of the teacher can be heard in the children's discourse when the teacher is not about, especially in the form of appeals to some authoritative basis for how some problem should be resolved" (p. 29). Some of the articles in this group also recommend that, at times, the teacher must step aside and allow students to both technically and socially work things out on their own (Roth & Bowen, 1995; Roychoudhury & Roth, 1996).

Other authors (Dawes, 2004; Mercer et al, 2004; Mercer & Fisher, 1992; Mercer et al., 1999 ) argue for the explicit teaching of certain linguistic practices that are highlighted in *National Science Education Standards* (NRC, 1996). These authors point out that science classroom debates are likely to sound like daytime television talk shows unless the skills of dialogic argument are explicitly taught and modeled by the science teacher.

*Influence of learning activities on pedagogical context*

Teachers also shape the pedagogical context of the classroom through the science-learning activities that are selected for the class. Science-learning activities are a focus in *Benchmarks for Science Literacy* (AAAS, 1993)**.** From the chapter on scientific inquiry;

> Another, more ambitious step is to introduce some student investigations that more closely **approximate sound science** . . . students working individually or in teams should **design** and **carry out** at least one **major investigation**. They should **frame the question**, **design the approach**, **estimate** the **time** and **costs** involved, **calibrate** the **instruments**, **conduct trial runs**, **write** a **report** and finally, **respond** to **criticism.** (p. 9, emphasis added).

Students are being called upon to behave in the fullest sense as scientists.

*Science For All Americans* (AAAS, 1990) is equally clear:

> If students are expected to **apply ideas in novel situations**, then **they must practice applying them to novel situations**….[S]tudents cannot learn to think critically, analyze information, communicate scientific ideas, make logical arguments, work as part of a team and acquire other desirable skills unless they are permitted and encouraged to do those things over and over in many contexts. (p. 16, emphasis added)

The document elaborates on the “other desirable skills” by listing computation and estimation, manipulation of variables, and observation of phenomena, and, finally, critical response skills. *Science For All Americans* (AAAS, 1990) also promotes the acquisition and exercise of attitudes and values that are particular to science. Among these are curiosity, openness to new ideas, and informed skepticism. Once again, teachers are being called upon to provide activities that initiate their students into the cultural practices and values of the scientific community.

The Georgia State Department of Education Georgia Performance Standards (GPS) for Science (Georgia State Department of Education, 2005) are aligned with *Benchmarks for Science Literacy* (AAAS, 1993) and *National Science Education*

*Standards.* Therefore, they reflect the same themes of action and values that are a part of those earlier documents. Quoting from the science section of GPS (GSDOE, 2005)**,**

> The Georgia Performance Standards are designed to provide students with the knowledge and skills for proficiency in science. The Project 2061's *Benchmarks for Science Literacy* is used as the core of the curriculum to determine appropriate content and process skills for students. The GPS is also aligned to the National Research Council's *National Science Education Standards*. Technology is infused into the curriculum. The relationship between science, our environment, and our everyday world is crucial to each student's success and should be emphasized.

Quoting from the GPS document: "Our goal is for students to Do Science, not View Science."

From the literature there are studies and theoretical articles that indicate that the sorts of activities chosen and the way that those activities are chosen for the class have a strong impact on the pedagogical context of the classroom. Several authors (Mercer et al., 1996; Mercer et al., 2004; Roth & Bowen, 1995; Roychoudhury & Roth, 1996; Salyer, 2000) present evidence that when teachers or the students themselves choose activities that provide opportunities for students to practice being scientists, the students engage in the use of certain language, make symbolic representations of data, and construct rules for privileging knowledge that closely resemble the practices of scientists. Several of these authors make the argument that when activities are student-selected, students are more likely to "talk science" than when activities are teacher-selected (Roth & Bowen, 1995; Roychoudhury & Roth, 1996; Salyer, 2000).

Some of these same authors (Mercer, 1996; Mercer et al., 2004; Roth & Bowen, 1995; Roychoudhury & Roth, 1996) and others (Jimenez-Aleixandre et al., 2000; Watson et al., 2004) note that the quality that Mercer et al. (1994) call openness may be at the heart of students' perception that that an activity requires or is worthy of inquiry.

Openness means that the students perceive that activity offers a number of potentially fruitful avenues of inquiry for problem-solving. When students do not sense the openness of an activity they fall back on approaches that have been successful in teacher-centered or cookbook sorts of activities (Jimenez-Aleixandre et al.; Watson et al.).

The key science education documents make recommendations that relate directly to elements of Lemke's (1990) "talking science" and to elements of socially situated activities, linguistic habits, and values that Gee (2004a) identifies as elements of Science Discourse. They recognize the role of language in creating a context in which students learn science acting as scientists. The science education literature also documents this key role of language. The research also links the learning context in the science classroom and the language that is used with the learning activities that are selected and the role that the teacher takes in teaching them. However, a great deal remains to be discovered about the specific ways that students and teachers use language as they enact the various Discourses that are part of learning science.

Critical Discourse Analysis (CDA) is a means of examining these language acts and coming to understand how language is used in determining what activities count as science, how power and resources are apportioned, how and what relationships are made and maintained, how and what knowledge is privileged, and how and what identities are constructed (Gee, 2005; Lemke, 2001).

A basic tenet of this study is that inquiry activities may be a fertile medium for learning science because they provide the opportunity for teachers to model or scaffold the practices and values of the scientific community and for students to engage in the sorts of technical and social activity that is typical in communities of scientific practice.

The modeling and scaffolding of the teacher, as well as the activities of the students, depend on language that is situated in the activity and the context of the particular classroom.

The relationship between teacher-centered and student centered science learning activities and the sort of language that accompanies them is well documented in the literature. There is even some indication that students and teachers may also use language in conjunction with these different activities to enact different identities. There is, however, a gap in the science education literature concerning a description of how students and teachers who are engaged in learning science use language to enact the Discourses of the science learning, and how these different Discourses may contribute to the enactment of different identities. This study proposes to provide a rich description of the ways that language is used to enact those Discourses and how the Discourses make enactment of science learning identities possible. This description will be useful to researchers because it will clarify the nature of the social interactions that accompany efforts at learning science in different pedagogical contexts.

Many previous studies have been conducted in foreign countries or in special environments, such as private schools or schools affiliated with foundations or research institutions (Mercer et al., 1994; Mercer et al., 2004; Mercer & Fisher, 1992; Mercer et al., 1999 ; Rosebery et al., 1992; Roth, 1993; Roth & Bowen, 1995; Roth & Lawless, 2002; Roth & Lucas, 1996; Roth & Lucas, 1997; Roychoudhury & Roth, 1996; Tao, 2001; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001; Warren & Rosebery, 1996). This study will be conducted in public school. In addition, this study will focus on a larger community of learners than previous studies, which in many cases have focused on student dyads. The study's location in a suburban high school will help to fill a gap in the science education literature and will make its results more meaningful to the majority of practitioners who are situated in public schools.

The linguistic analysis that comes from this study may be useful to practitioners by providing suggestions for using inquiry activities in their classrooms. The insights that come from this study might also be useful to practitioners by providing guidance in the design and implementation of inquiry activities that will result in the sorts of social practices that lead to meaningful science learning.

This study is valuable because it emphasizes that learning science is a social endeavor. It emphasizes that, as social endeavor, learning science in the most meaningful sense resembles the social endeavor of scientific practice itself. For practitioners it can serve as a guide and a reminder that the learning activity is only a plan, lifeless and meaningless. The learning activity is imbued with life and becomes meaningful to learning science only when it becomes the center of human social behavior.

## Guiding Questions

Science is a complex socially situated activity with its own particular linguistic practices, values and social structure (Driver et al., 2000 ; Dunbar, 1995 ; Duschl & Osborne, 2002; Gilbert, G. N. & Mulkay, 1984; Lemke, 1990). Learning science is also a situated social activity that is heavily influenced by pedagogical context (Lemke, 1990). When the pedagogical approach to science is inquiry, the linguistic interactions, values and social structure of students resemble the linguistic interactions, values and social structure of practicing scientists (Kelly, Brown, & Crawford, 2000 ; Roth & Bowen, 1995; Roychoudhury & Roth, 1996; Salyer, 2000). For both scientists and students learning science through inquiry, these situated linguistic practices, along with the accompanying values and social structures, constitute what Gee calls a Capital "D" Discourse.

*Science for All Americans* (AAAS, 1990), *Bench Marks for Science Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 2000) call on science educators to provide students with student-centered inquiry learning experiences that enable them to participate in Science Discourse as the means of leaning science. Learning science in this way has an impact on the students' level of conceptual understanding, their ability to reason through science problems, and their understanding of Nature of Science (Kelly, Brown, & Crawford, 2000 ; Lemke, 1990; Roth & Bowen, 1995; Roth & Lucas, 1997; Roychoudhury & Roth, 1996; Salyer, 2000).

In spite of the recommendations of *Science for All Americans* (AAAS, 1990), *Bench Marks for Science Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 2000), Inquiry is a rare pedagogical approach, and in most public school classrooms pedagogy is teacher-centered (Hogan, Nastasi, & Pressley, 1999; Kawasaki, Rupert Herrenkohl, & Yeary, 2004; Lemke, 1990; Mueller, 2002; Newton et al., 1999 ; Ritchie & Tobin, 2001). This arrangement results in students' "doing the lesson" rather than "doing science." The ways that language is used when activities are teacher-centered is also complex and tied to the types of activities that students do, the values that the students hold and the social structure that is part of those activities (Bloome et al., 1989; Jimenez-Aleixandre et al., 2000; Lemke, 1990; Watson et al., 2004).

While these ideas are well documented and are widely accepted in science education literature, little has been done to clarify exactly how students and teachers enact their classroom Discourses and how pedagogical context of the classroom influences these Discourses and their enactment. When student or teacher discourse in a science classroom has been examined, these studies have generally focused on only the language, or lower case "d" discourse (Durham, 1997; Hellermann, Cole, & Zuengler, 2001; Hogan, Nastasi, & Pressley, 1999; Mercer, 1996; Mercer et al., 2004; Roth, 1993; Stamovlasis, Dimos, & Tsaparlis, 2006; Suthers & Toth, 2003), as opposed to Gee's upper case "D" Discourse which takes into account a broad range of issues that are intimately associated with the situated use of language.

Further, when studies of students' and teachers' science learning/teaching discourses have been conducted, these studies have frequently been with students and teachers in schools outside of the United States. Some of these studies have been conducted in special settings such as private schools, or in schools associated with research institutions (Mercer, 1996; Mercer et al., 2004; Rosebery et al., 1992; Roth, 1993; Roth & Bowen, 1995; Roth & Lucas, 1996; Roth & Lucas, 1997; Roychoudhury & Roth, 1996; Tao, 2001; Warren & Rosebery, 1996). Additionally, many of these studies have focused on small groups rather than the larger groups of learners that function as a community of science learners (Mercer, 1996; Mercer et al., 2004; Mercer et al., 1999 ; Stamovlasis, Dimos, & Tsaparlis, 2006; Suthers & Toth, 2003; Tao, 2001).

Finally, there are no current studies of language use in the context of an extracurricular activity that have extensively employed Gee's concept of Capital "D" Discourse in this context. Employing Gee's idea of Discourse allows the researcher to examine the reflexive interaction of extracurricular science learning context and language. This permits the researcher to shed light on the elements of context that contribute to the enactment of the Discourses that are developed within this unusual learning context.

In an effort to fill the above-highlighted gaps, in the context of public school classroom community, this study proposes to focus on two questions involving Discourses in the science classroom:

1. How do science teachers and their students enact Discourses as they teach and learn science?
2. How does the pedagogical approach of a learning activity facilitate the Discourses that are enacted by students and teachers as they learn and teach science?

*Question 1*

The focus of this study is students' and teachers' Discourse in the sciencelearning. Given that learning science is a complex social activity that requires students to use language, in the context of particular culturally situated activities, symbolic practices, values and community, learning science constitutes a Discourse (Gee, 2001; Lemke, 1990). Human beings build realities by using language in conjunction with other means of communication to accomplish certain tasks that Gee refers to as Building Tasks. To a significant degree, the way that language is used to accomplish these tasks governs the potential outcomes that may emerge from a given social context (Gee, 2005; Halliday, 1978; Lemke, 1990). If the goal of the teacher and the students in a science classroom is to learn science in a particular way, then the way that language is used to enact particular

Discourses will have a strong impact on the way that science is learned (Driver et al., 2000; Lemke, 1990; Roth & Bowen, 1995; Roth & Lucas, 1996; Roth & Lucas, 1997; Roychoudhury & Roth, 1996). If the goal of the teacher and the students is to learn science as recommended by *Science for All Americans* (AAAS, 1990), *Bench Marks for Science Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 2000), then the Discourse that students and teachers must enact will be very similar to the Discourse of practicing scientists. This question focuses on how the Building Tasks are used to enact students' and teachers' classroom Discourses.

*Question 2*

Language is reflexive. This is to say that language is always selected because of a particular context; however, the language used in a particular context also influences the nature of the particular context (Gee, 2005; Schiffrin, Tannen, & Hamilton, 2003). The pedagogical activity that is selected for the classroom is one of the principal factors which determine the context in which learning will occur and the type of learning that will be possible in that context (Duschl & Osborne, 2002; Lemke, 1990; Mercer, 1996; Mercer et al., 2004; Roth & Bowen, 1995; Roychoudhury & Roth, 1996). Regardless of the pedagogical activity selected for the class, language in some form will be a part of that activity and the language that is used will in some way shape the context in which the activity occurs.

## Theoretical Framework

Two theories inform this research. One is Social Constructivism, and the other is Critical Discourse Analysis. Social Constructivism is most strongly associated with Russian psychologist and philosopher Lev Vygotsky. Vygotsky viewed learning as a social undertaking wherein meaning and understanding emerge from interactions between an individual and more competent members of a society, or from the artifacts of that society. In Vygotsky's view, since language and other artifacts of the culture that might be employed in learning are social constructs, they will vary from culture to culture as suits the needs and history of those cultures (Resnick, Salmon, Zeitz, Walthan, & Holowchak, 1993).

Critical Discourse Analysis (CDA) is a chimeric creature; it is, at once, both a theory and a method (Rogers, 2004; van Dijk, 2003; Wodak, 2001; Wood & Kroger, 2000). Having noted this, the above-cited authors note that it has its philosophical roots in the Critical Theory associated with the Frankfurt School of the post-1950s. There are many philosophers who have contributed to the development of Critical Theory, but latter-day proponents of the critical theory on which CDA is founded are Jürgen Habermas and Paolo Freire (Crotty, 1998; van Dijk, 2003).

The origins of CDA can be traced to the work of these two philosophers. Habermas' contribution to CDA is his examination of critical theory as the tension between what he referred to as communicative competence and communicative rationality, on the one hand, and distorted communication on the other (Crotty, 1998). Freire's contribution to CDA is his concept of language as a way to expose oppression, and language as an action against oppression.

As it is most often described, Critical Theory (Kincheloe & McLauren, 1994, pp. 139-140, in Crotty, 1998) holds:

- that all thought is fundamentally mediated by power relations that are social in nature;
- that facts can never be isolated from the domain of values or removed from ideological inscription;

- that the relationships between concept and object, and between signifier and signified, is never stable and is often mediated by the social relations of capitalist production and consumption;
- that language is central to the formation of subjectivity, that is, both conscious and unconscious awareness;
- that certain groups in society are privileged over others, constituting oppression that is most forceful when subordinates accept their social status as natural, necessary or inevitable;
- that opposition has many faces, and concern for only one form of oppression at the expense of others, can be counterproductive because of the connections between them;
- that mainstream research practices are generally implicated, albeit often unwittingly, in the reproduction of class, race and gender oppression.

As quoted above, Lemke's list includes "observing, describing, comparing, classifying, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing, lecturing, and teaching in and through the language of science" (Lemke, 1990, p. 1). Linguistically, the views of both authors are parallel and in agreement (Gee, personal comment, 11/15/05; Lemke, personal comment 11/18/05).

Gee and Lemke hold that the language that teachers and students use in the science classroom is situated in the context of the classroom. This situated language is employed to accomplish certain social tasks that are necessary to enacting Discourse (Gee, 2005). The activities that are used in the classroom are important to the context of the classroom. As context changes, the language that is used in the classroom will change, and the way the Building Tasks are used will change too (Gee, 2005; Roth & Lucas, 1997; Roychoudhury & Roth, 1996).

Discourse will serve two purposes in this study. Firstly, in the big "D" form, where Gee (2001) and Wells (2000) mean the purposeful use of language, Discourse will be a means of teasing out the identities, values, and social structures that are connected with the languages that teachers and students employ in learning/teaching science. In the second, small "d" sense, where discourse refers to the actual language in use (Gee, 2005), discourse will be a source of data to which CDA will be applied in an attempt to construct a way of understanding how Discourses are being enacted in the science classroom.

## Methodology

This study investigated the language that students and teachers used as they learn/teach science. Because it sought to construct "an accurate reflection of the views and perspectives of the participants in the research" (LeCompte & Schensul, 1999, p. 12), this study will use a qualitative methodology. I will use CDA as a method to analyze data from the language that is observed as the students and their teachers learn/teach science. These observations and their analysis will provide data that are "rich in description of people, places, and conversations" (Bogden & Biklen, 2003, p. 2).

This research grew out of several influences. The first was several authors who write of learning science as acquiring a specialized literacy or a language (Itza-Ortiz, Rebello, & Zollman, 2003; Lee, 2001; Lee & Fradd, 2003; Lemke, 1990; Williams, 1998). The second is an article by Gee (2001) in which he writes of acquiring literacy, not as the mere process of learning to read, but as the acquisition of a much broader and varied set of skills, attitudes and beliefs within the context of a particular social setting and its institutions. Gee calls this process "acquiring Discourse". The third and final source is a study by Roth and Lucas (1997) in which the authors used discourse analysis as a qualitative methodology to tease out the ontological and epistemological commitments that students used to form their World Views. It is the linkage of the ideas concerning literacy with CDA as a technique that could be used to construct a description of how science students and teachers enact science learning/teaching Discourses, that gave rise to this study.

CDA is at once a qualitative interdisciplinary methodological approach and a set of methods that are employed in analyzing linguistic data collected in naturalistic settings. This having been note, discourse analysis is a qualitative methodology with some important differences between itself and both quantitative and other qualitative approaches. Wood and Kroger (2000) write generally of discourse analysis:

> [d]iscourse analysis is thus not simply an alternative to conventional methodologies; it is an alternative to the perspectives in which those methodologies are embedded. Discourse analysis entails more than a shift in methodology from a general, abstracted, quantitative to a particularized, detailed qualitative approach. It involves a number of assumptions that are important in their own right and also as a foundation for doing discourse-analytic research (p. 3).

Chief among those assumptions is that *language is action* and that *language constitutes reality*; it is not an expression of some pre-existing or underlying discourse-independent reality. In keeping with the Constructivist and Poststructuralist traditions from which it is drawn, discourse analysis regards language as *real* and an entity to which qualitative methods may be applied and from which the analyst constructs a *subjective interpretation* of a discursively constructed reality (Crotty, 1998; Gee, 2005; Rogers, 2004; Wodak, 2001; Wood, L. A. & Kroger, 2000).

CDA does not permit a researcher to divine the intended meaning of utterances or other semiotic production (Schriffin et al., 2003). Instead, CDA allows the investigator to ask and answer questions about how language in a social context is used to create social reality and how the context and power in that context shape the way the language is used (Gee, 2005; Schiffrin et al., 2003).

Records of language were data sources for this study. These included videotaped records of students' and their mentors' spoken language, semiotic representations employed by teachers/sponsors and students. CDA, in a form similar to that advocated by Gee (2005, 2004a) and to a lesser degree by others (Scollon, 2001; van Dijk, 2001; Wodak, 2001 ), was applied to transcripts of student and mentor language from robotic team activities and semi-structured interviews. Videotaping will ensure that accurate and complete records of language situated in the context of the class' activities will be available for transcription.

Verbatim transcripts of language were be produced from the videotapes. Attention was paid to gesture, intonation, emotion and proxemic elements of the activities. Gee's (2005) Building Tasks will provide categories for a priori codes. The codes were constructed around thematic regularities that are observed in the language writing and other semiotic products produced by the robotics team members and their sponsors. The Building Tasks were particularly useful categories for codes because they are a list of the ways that language is used to build seven areas of reality and are also a means through which discourse analysts can ask questions about how language is being used (Gee, 2005). This coding process was the first step in the construction of an account of how students and teachers enacted their science learning/teaching Discourses in the context of an open inquiry science learning pedagogical approach and how the pedagogical context for teaching and learning science facilitated the enactment of those Discourses.

The methodology that I employed in this study depends on a human observer and evaluator. I come to this research with biases. I embrace constructivism as an approach to both epistemology and pedagogy. I feel that inquiry is the approach to education that is most successful in forming and equipping citizens capable of functioning responsibly in a representative democracy. To minimize the impact of these biases on this research, I used member-checking and peer debriefing. Since the participants in the research and an experienced researcher from outside the study agreed with the accounts that I constructed through my analyses, it is less likely that my biases have dominated my conclusions. The comments of participants and the peer debriefer were also useful in helping me to evaluate emerging hypotheses and in suggesting changes in methodology. In addition, the analyses that I applied to student and teacher language considered not only what was said, but also how it was said and the structure of that language, as well. Since these approaches to the analysis all converged on similar interpretations of the language that teachers and students were using as they taught/learned science and talked about teaching/learning science in the context of robotics and the science classroom, it is unlikely that the accounts of the participants' Discourses were solely the products of my biases (Bogden & Biklen, 2003; Gee).

## Summary

Both doing science and learning science are social undertakings that are associated with certain language, activities, and values. As such, both constitute Discourses. In the case of scientific practice, the Discourse is highly codified and stable (Halliday, 1993; Toulmin, 1958). However, the discourses associated with learning science seem to vary depending on the pedagogical context in which the learning is situated (Gee, 2004b; Lemke, 1990; Roth & Lucas, 1997; Roychoudhury & Roth, 1996; Toulmin, 1958).

In the context of inquiry, students have opportunities to engage in many of the activities associated with the practice of science. Important education documents such as *Science for All Americans* (AAAS, 1990) and *Inquiry and the National Science Education Standards* (NRC, 2000) endorse learning science through engagement in many of the activities regularly employed by practicing scientists, and identifies inquiry as the context in which these activities are most prevalent. The activities that *Inquiry and the National Science Education Standards* (NRC, 2000) recommends are not the mere practice of sound lab techniques; they include linguistic habits, ways of thinking, ways of privileging knowledge, ways of representing ideas and ways of relating with others to build a community of learning. *Inquiry and the National Science Education Standards* (NRC, 2000) is recommending that students enact Science Discourse.

In spite of these recommendations, the dominant mode of teaching science in the United States is teacher-centered and offers students little opportunity to try on being scientists (NRC, 2000). Even though teachers and school administrators say that they favor student-centered approaches such as inquiry (Tobin et al., 1997; Tobin & McRobbie, 1996), they are reluctant to change their practice, and classes remain teacher-centered (Driver et al., 2000; Lemke, 1990). In the context of teacher-centered science learning, students and teachers engage in particular activities, use particular language and embrace particular values. Teacher-centered classrooms require students and teachers to adopt particular Discourses that are customized to the learning context (Driver et al., 2000; Gee, 2004b; Lemke, 1990).

If the goals of important policy documents, such as *National Science Education Standards and Inquiry* (NRC, 1996) and the *National Science Education Standards*

(NRC, 2000), are to be met, both students and teachers will need to enact different Discourses, and teachers will need to create the contexts in which these Discourses are possible. The research that I propose will provide descriptions and insights into the nature of the Discourses that students and teachers enact in different pedagogical contexts, and will provide a rich description of how these contexts facilitate the enactment of those Discourses.

The focus of this study was a high school extracurricular science and technology activity, a robotics team, which was dominated by student-centered inquiry designed to teach and learn science principles and technology. This context offered opportunities to observe the activities of the students and their teachers/sponsors and to record their language as they did these activities. These observations and recordings, along with video recordings of language from semi-structured interviews, were the data to which CDA was applied. CDA provided a means of understanding and describing the Discourses that were enacted, and of determining how the pedagogical context of the activities facilitated their enactment. Developing these descriptions and insights led to recommendations for creating the contexts that led to the sort of science learning that is recommended in the NRC documents. Further, an understanding of the way that language is used in these different learning contexts, and how that language and context are shaped by powerful social forces, helped to provide an explanation for why open inquiry science learning is so rare in public school classrooms in the United States, and why teachers, administrators, and policy-makers are so resistant to open inquiry learning.

# CHAPTER 2

# REVIEW OF LITERATURE

The focus of this study is how the language that is used to learn and teach science changes with the different contexts created by different sorts of learning activities. For the purpose of this study, language in its broadest sense is the focus of the study. This focus is warranted because language is the primary resource that science teachers and science students employ in their teaching and leaning activities (Lemke, 1990, p. 26). Further, many researchers (Driver et al., 2000 ; Mercer et al., 1994; Roth & Bowen, 1995; Roth & Lawless, 2002; Roth & Lucas, 1996) regard science and the learning of science as a discursive activity through which scientists, students and teachers create communities, form systems of values and through which individuals enact identities. Gee (2005) calls language so defined a capital "D" Discourse. This study will examine student and teacher Discourse in the changing contexts that exist in a science learning activity, a robotics team.

The focus questions for this study were as follows:

1. How do science teachers and their students enact Discourses as they teach and learn science?
2. How does the pedagogical approach of a learning activity facilitate the Discourses that are enacted by students and teachers as they learn and teach science?

The purpose of this chapter is to place this study within the context of related research that has been done, to define the areas in which this study overlaps with current research and to highlight the aspects of this study that extend the scope of previous research.

## Science Reconsidered

A review of the pertinent literature connected to my research interests must include a review of some of the theoretical writings that recast the status of science during the period after World War II to the present. This approach to the literature is warranted because the changes in epistemological and ontological views that placed science fully within cultural context are the same as those that are, in part, responsible for the development of the philosophical, theoretical and methodological frameworks that currently dominate research of language in the science classroom. A recounting of these changes in the conception of Nature of Science takes on added importance, since many of the recommendations for and implementation of reforms in science education have centered on making science teaching and learning as much as possible like scientific inquiry. This recasting of science came about through the shift in worldview that occurred as many philosophers of science abandoned the realist worldview of Logical Empiricism for Constructivism (Abd-El-Khalick & Lederman, 2000), and many social scientists abandoned the outlook of Modernism for Postmodernism (Lemke, 1994). These larger shifts in the philosophical underpinnings of modern science and its social science allies made much of the current research into the use of language in the science classroom both possible and necessary.

Prior to these important works, science was regarded as a purely positivistic empirical pursuit that operated separately from all other aspects of culture. The works that I shall discuss re-characterized science as one of many social activities that is governed and influenced by the same forces as any other socially-mediated activity. These theoretical works are important because as science began to be viewed as a fully social activity, the language practices of scientists became an important subject of study.

Abd-El-Khalick and Lederman relate that prior to World War II, philosophy of science had been dominated by the realist philosophy of philosophers like Rudolf Carnap, Karl Popper, Hans Reichenbach, Kurt Gödel and Bertrand Russell, among others, who differentiated between the context of scientific discovery and the context of scientific justification (Abd-El-Khalick & Lederman, 2000). These philosophers were concerned with how scientific theory was justified and the context in which those justifications were made. These philosophers averred that science should be limited to phenomena that could be investigated through purely empirical means, and that justification for findings related to these phenomena should rest on the rules of symbolic logic.

In the social sciences, the modernist view held that objective knowledge is the product of the individual mind, that this knowledge corresponds to things in the real world and that the significant details of this world of reality are the same to everyone. Postmodernism opposes this view and holds that knowledge is a story, a text or a discourse that, according to Lemke (1994),

> puts together words and images in ways that seem pleasing or useful to a particular culture, or even just to some relatively powerful members of that culture. It denies that we can have objective knowledge because what we call knowledge is constructed using linguistic tools that vary from culture to culture that can see the world in very different ways, all of which “work” in their own terms. (p. 1)

After World War II , logical positivism came under attack by Paul Feyerabend, Bas van Fraassen, Thomas Kuhn and Ernst von Glasersfeld. These philosophers may be placed under the big tent of a post-modernist philosophy of knowledge and science called constructivism. Unlike the positivist philosophers, these constructivist philosophers of knowledge and science were more interested in the social and historical context of discovery than in the justification of discoveries as real reflections of things that scientists had found in nature. The debate that ensued between these competing philosophical views is not yet resolved. Michael Matthews, a frequent critic of the constructivist side of this debate, writes that although constructivism has gained a predominant position among many philosophers in most industrialized Western liberal democracies, “Professional opinion is, to put it mildly, divided on its [constructivism’s] philosophical merits” (1998 p. 165).

One of the early attacks on logical positivism came during the 1950’s, when Feyerabend (1993) attacked logical positivism’s account of scientific justification in his work *Against Method*. In this work, Feyerabend argued that the positivist’s account of scientific method was too restrictive. He objected to the requirement that a new theory be consistent with an older theory that might be under attack, and argued that this requirement gave an unfair advantage to the old theory. He suggested that if a long-standing theory were challenged by two new theories with equal explanatory power, a choice between the challenging theories would favor the candidate theory that was more consistent with the accepted theory. While this choice may not, at first, seem objectionable, the choice of the particular challenging theory might be made as much for esthetic or social reasons as for rational ones. Feyerabend also suggested that the choice in favor of the theory consistent with the older theory saved the scientific community from having to abandon cherished prejudices. Finally, Feyerabend argued that the positivists' insistence that a theory be consistent with all relevant observations placed an undue burden on the new theory, since no interesting theory is ever consistent with all relevant facts (1993).

The attack on positivism continued in Stephen Toulmin's 1958 book, *The Uses of Argument.* In this work, Toulmin attacked positivistic absolutism that holds that there are universal truths that can be derived from the idealized principles of formal logic. Toulmin set out to show that, while there may be certain standard moves in any argument, these field-invariant aspects of an argument (Claims, Data, Warrants, Backing, Qualifiers and Reservation) are inadequate to describe the way that arguments are carried out and evaluated in varying contexts. He pointed out that among lawyers, theologians and scientists, what might qualify as a valid, well-thought-out argument varied considerably, and these determining field-dependent aspects of argument frequently hung on linguistic conventions that were peculiar to the particular field under consideration (Toulmin, 1958).

Other authors, such as Kuhn, were interested in revealing the historical context of scientific discovery. Kuhn's approach stood in contrast to realist social scientists, who, during the first half of the twentieth century, were interested in the social structure of science rather than accounts of how society and culture shape the actual scientific process and the knowledge that science produces (Abd-El-Khalick & Lederman, 2000). This constructivist approach took into account the psychological and sociological factors that Kuhn, La Tour, and others saw as the ontological and epistemological bases of science, but which the positivists regarded as external to science (Abd-El-Khalick & Lederman, 2000). Through this newer History/Philosophy of Science, science was transformed into a wholly human endeavor; it was placed fully into the human mind and made subject to the full range of human potentialities (Abd-El-Khalick & Lederman, 2000).

Bas van Fraassen continued the assault on logical positivism with his work *The Scientific Image.* Van Fraassen (1980) argued against scientific realism's contention that the aim of science is to discover true theories. He maintained that a more reasonable, and actually attainable, aim for science is to discover empirically adequate theories. Adequate theories are theories that fit the observable facts sufficiently well. Van Fraassen called this view "Constructive Empiricism." Van Fraassen argued that the realists' view requires that a theory give a literally true account of something that actually exists and operates in nature (van Fraassen, 1980). Van Fraassen argued that this position is difficult because empirical evidence alone is never sufficient to establish this sort of theoretical truth. Van Fraassen referred to the disparity between true scientific theory and empirically adequate theories as the empirical underdetermination of theories. Under this thesis, empirical evidence can only establish that a theory is empirically adequate and capable of making successful predictions of other empirical data. Van Fraassen (1980) continues his argument by pointing out that in addition to their predictive abilities, theories are assessed by other, non-empirical standards. These standards are simplicity, parsimony, and elegance. Since these are not empirical judgments, these standards, according to the realist, cannot justify belief in the literal truth of a theory (van Fraassen, 1980). Therefore, the believability of a theory frequently rests as much in the arguments that were constructed on its behalf as on the evidence in support of the theory.

Van Fraassen's view of science, Constructive Empiricism, has become part of a broader epistemological view called constructivism. Constructivism in its most extreme or radical form is most strongly associated with von Glasersfeld (1984). While van Fraassen's constructivism doubts the literal truth of scientific theories, it is still rooted in the scientific community's agreement as to the fit between theoretical notions and empirical evidence, von Glasersfeld extends constructivism by placing judgment of epistemological verity in the experience of the individual. Von Glasersfeld (1984) calls his epistemological stand Radical Constructivism, "because it breaks with convention and develops a theory of knowledge in which knowledge does not reflect an objective, ontological reality but exclusively an ordering and organization of a world constituted by our experience" (p. 128). This approach to knowledge is an extension of van Fraassen's Constructive Empiricism, and its implications for science are striking.

In a 1993 lecture, von Glasersfeld elaborated on this theme, stating that "Constructivism is an attempt to cut loose from the philosophical tradition that knowledge has to be a representation of reality, where reality is spelled with a capital and means a world prior to having been experienced" (p. 26). The constructivist view of science is that knowledge is only possible through individual experience. Experience comes through the senses, and one of the most important types of sense experience is communication with other humans. Each individual uses his/her experiences to construct his/her own view of nature and these individual constructions constitute reality. An individual's experience and observations of culture may convince the person that his/her individually constructed reality may be very similar to other individually constructed realities. However, as language is employed to establish the similarities between constructed realities, the person finds that language is limited and never yields more than inexact representations of those realities (Quine, 1960). Thus, it is not possible to be sure how closely his/her reality matches another's. This view may prompt the question: Are some realities more real than others? In constructivism, this question is meaningless, when considered outside of the individual's culturally mediated experience of the world. It is, however, meaningful to ask if decisions made on the basis of certain constructed realities are more successful in their predictive powers. Von Glasersfeld (1993) refers to such constructed realities as being more viable and states that "just as some ways of 'acting' work and others do not, so some of our conceptual theories work and others do not " (p. 26).

Finally, M. A. K Halliday (1978), in his book *Language as Social Semiotic*, examined semiotics, meaning-making, within language communities. Halliday concluded that the way meaning was constructed by a language community was more important than the meaning-relations of the signs. By the conventions of social semiotics the meaning-making relations among signs are simply a resource that users of the language may employ in meaning-making. The various ways of deploying these semiotic resources are strongly contextual, and are specific to a culture and community. Halliday (1978) regards science as a culture.  By treating science as a culture, Halliday and Martin (1993) assert that the socially situated linguistic practices used by scientists in their work are more important to the practice of science than the system of meaning-relations among the words, mathematical expressions, graphs, tables and illustrative diagrams that they employ in bringing meaning to science.

## Science Education Recast

The current review of literature is necessary because the recasting of science during this period has also been influential in shaping science education and recasting the philosophical, theoretical and methodological frameworks that currently dominate research of language in the science classroom. Shifts in worldview do not conveniently begin and end at particular well-defined points. This account begins after World War II. It could have begun, as von Glasersfeld (1984) does, by tracing constructivism as an epistemological stance to Giobattista Vico in the Enlightenment, but as Lemke (1994) argues, in marking the boundaries between philosophical movements or social trends, it is only in retrospect that these changes are noted, and the accounts of the changes are written by the new dominant view. The same can be said of the current and dominant approach to research of language in schools in general and science classrooms in particular. However, a convenient and defensible dividing line might be drawn at the 1990 publication of Jay Lemke's *Talking Science*.

Using *Talking Science* (1990) as a dividing line is a defensible choice because Lemke makes a clean break from the philosophical, theoretical and methodological approaches that were dominant in studies of language in the science classroom prior to its publication. In these studies, researchers counted numbers of student utterances and teacher utterances in an effort to establish who talked most. Although prior to *Talking Science,* some research on language in the classroom had drawn on the philosophy, theory and method employed by Lemke in *Talking Science* (Mehan, 1979; Sinclair & Courtland, 1975), it is clear that, for its time, *Talking Science* presents the most fully synthesized post-positivist and post-modernist view of science and use of language in science education. What really separates the research in *Talking Science* from its predecessors is the emphasis on the context of the language used in the science classroom (Lemke, personal comments, 3/3/07). This attention to context is a feature that dominates current studies of language in education (Gee, 2005). Further, *Talking Science* provides a convenient dividing line because it is a major work that is widely cited and, judging by these frequent citations, it is highly regarded by the academic community.

Lemke's research in *Talking Science* reflects and incorporates a philosophical and theoretical view of science and of science education that was coming to prominence in educational academia in the 1980s and 1990s. *Science for All Americans* (1990), a seminal work in the science education literature of this period, reflects these trends. As part of Project 2061the American Association for the Advancement of Science (AAAS) produced *Science for All Americans* an extremely important document because it is the product of a prestigious, main-line organization and it reflects much of the post-World War II re-characterization of science. Its recommendations form the basis of many of the reforms that have been proposed and implemented in science education over the last 20 years. It characterizes the state of science education at the time of its writing as

> emphasizing learning answers more than the exploration of questions, memory at the expense of critical thought, bits and pieces of information instead of understanding in context, recitation over argument, reading in lieu of doing. [Its practitioners] fail to encourage students to work together, to share ideas and information freely with each other, or to use modern instruments to extend their mental capacities. (p. xvi)

The comparisons that form the structure of this passage become recurring themes and finally recommendations for reform in this document. These comparisons highlight a contrast between science education that is done to students as opposed to science education that is done by students; a contrast between science knowledge that is received and science knowledge that is constructed through personal experience; a contrast between science knowledge that resides in the individual and science knowledge that is socially constructed. To achieve these reforms, *Science for All Americans* (1990) recommends that science teaching be consistent with the nature of scientific inquiry.

Science, mathematics and technology are defined as much by what they do and how they do it as they are by the results they achieve. To understand them as ways of thinking and doing, as well as bodies of knowledge, requires that students have some experience with the kinds of thought and action that are typical of those fields (p. 200).

Lemke's own recommendations for science education in *Talking Science* (1990) echo the recommendations that are found in *Science for All Americans*. Lemke puts it this way:

> Learning science means learning to *talk* science. It also means learning to use this specialized conceptual language in reading and writing, in reasoning and problem solving, and in guiding practical action in the laboratory and in daily life. It means learning to communicate in the language of science and act as a member of the community of people who do so. "Talking science" means observing, describing, comparing, classifying, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing, lecturing, and teaching in and through the language of science (p. 1).

Clearly, Lemke's writing in *Talking Science* (1990) reflects the view of science and the values and recommendations put forth in *Science for All Americans*. In *Talking Science* (1990), Lemke also employs post-modernist theory and methodologies such as discourse analysis. These theories and methodologies are reflected in his attitudes toward the use of language and have their origins in the post-modern philosophies of Edward Sapir, Benjamin Whorf, Mikhail Bahktin, Courtney Cazden, Michel Foucault, Ruqaiya Hasan and Michael Halliday (Lemke, 1990). Lemke's philosophical framework in *Talking Science* reflects and incorporates the ideas of post-positivist philosophers of science such as Richard Rorty and Jürgen Habermas and phenomenological philosophers such as Edmund Husserl and Ludwig Wittgenstein (Lemke, 1990). In *Talking Science,* Lemke's research questions and methodologies anticipate many of the questions and methodological approaches that have formed the basis for much of the research that has been done concerning language in the science classroom since the publication of *Talking Science*.

*Who Is Talking in the Science Classroom and What is the Significance of Their Talk?*

As with Lemke and *Talking Science* (1990), the literature on language use in science classrooms is concerned first of all with *who* is talking (in a broader sense, who is communicating.) and with *whom* they are talking (Dawes, 2004; DiSchino, Sylvan, & Whitbeck, 1996; Durham, 1997; Klaassen & Lijnse, 1996; Mercer, 1996; Roychoudhury & Roth, 1996). Secondly, Lemke and other researchers want to know *how* the parties are talking or communicating (Brown, 2004; Driver et al., 2000; Duschl & Osborne, 2002; Hammer, 1995; Simonneaux, 2001; Watson et al., 2004). Finally, researchers of language in the science classroom want to learn *why* the parties are talking or communicating (Duschl & Osborne, 2002; Mercer et al., 1994; Mercer et al., 1999 ). These questions and their answers will be the themes around which I will structure the review of literature on language in the science classroom. However, I will not be able to treat each of these separately because the answers to each of these questions frequently become tangled in some of the aspects of the answers to the other questions. I will note these situations as the review proceeds and deals with these particular aspects of language use in the science classroom.

This literature review will be somewhat wide-ranging. This breadth is necessary because of the sociolinguistic theory of language on which this study is based and the theory’s context-dependent nature. Since there are so many elements that contribute to the context of the science-learning, this review will rely on several areas of the educational research literature.

To the question, *who* in the science classroom is talking and with *whom* or at *whom* are they talking, the answer in many studies is straightforward. Generally the teacher is talking to or at the students (Durham, 1997; Graesser et al., 2002). At the high school level, the predominant mode of instruction is lecture, with questions asked by the teacher to the students. In this mode, the teacher will pause to ask students if they have any questions. However, it is rare for students to ask unsolicited questions of the teacher. An extensive study of classroom activities showed that approximately 75% of class time was tied up in teacher talk, while only 5% of class time was used to generate student response; of total class time only 1% was used to elicit open student responses that involved reasoning or opinions from other students (Goodlad, 1984).

Teacher Initiation, student Response and teacher Evaluation (IRE) is not the only sort of language pattern that takes place in the teacher-centered science classroom. Lemke (1990) describes several patterns. External Text Dialogue is a variation on triadic dialogue or IRE. In External Text Dialogue, the teacher's question is replaced by a text in the IRE pattern. Lemke calls another of these patterns Student Teacher Duolog. Student Teacher Duolog falls somewhere between IRE and Teacher-Student Debates. Either party may hold sway, but the primacy of student and teacher in the structure ebbs and flows. Either party may question the other; however, other students from the class are excluded from the activity. Both student and teacher may evaluate one another's responses at various points in the Duolog.

Finally, Lemke highlights True Dialogue. He points out that this is very rare in the teacher-centered classroom. True Dialogue always centers on a question that has no known correct answer. In the teacher-centered classroom this question originates with the teacher. The question may center on a student's opinion, on a real-life experience or on a question that has a wide range of possible answers. In True Dialogue there are teacher questions and student answers, and while the teacher may comment on the student's responses, there is no requirement for teacher evaluation. As Lemke (1990) notes, True Dialogue is rare, but it is most common when the theme of talk is not science! Generally, teachers formulate questions that have only one clear answer, and since many issues of judgment and opinion do not lend themselves to this style of questioning, such questions are not part of the language that occurs in science classrooms (Lemke, 1990, p. 55).

Lemke's version of dialogue is still teacher-centered. However, the teacher's role is different from that of the teacher in lecture, in IRE, in Student-Teacher Duolog, or even in Student-Teacher Debate. The main difference is in the power that the teacher holds as an authority. In True Dialog the teacher's authority is diminished. Since the teacher maintains the right to comment on student contributions in the dialogue or to terminate the dialogue means that he/she is still the authority, in the teacher-centered classroom, students' talk is controlled in important ways by the teacher.  I*n this arrangement, the teacher's talk centers on structural and thematic patterns that allow the teacher in the first case to control activities and in the second case to control the way in which subject-matter content is presented (Durham, 1997; Goodlad, 1984; Lemke, 1990).

The criticism of the activity patterns that were presented in the previous section is that they are teacher-centered. Teacher-centeredness is considered a problem in science classrooms because student inquiry into scientific questions should be the focus of these classes, and inquiry, in most cases, is not teacher-centered (Hammer, 1995; Martin-Hansen, 2002; van Zee, 2000). Inquiry is based in constructivist learning theory and pedagogy; therefore, it values the personal and social construction of learning by the student, along with his/her classmates. When activities in the science classroom are teacher-centered, teachers do most of the talking, and when students' talk, their talk is largely controlled by the teacher (Scott, 1998). Lemke's (1990) view is that when learning is a transmissive process, with the teacher functioning as the expert and provider of knowledge, there is really little need for students to talk with the teacher or their classmates in any meaningful way. On the other hand, when learning science is viewed as a social process that centers on inquiry, students' talk becomes an important element of the learning process.

Mueller (2002) identifies inquiry as an activity around which student talk occurs. Mueller explains that inquiry gives students an opportunity to articulate, defend and explain their ideas. Mueller and other researchers (Duschl & Osborne, 2002; Lemke, 1990; Roth & Bowen, 1995; Roth & Lawless, 2002; Roychoudhury & Roth, 1996; Stamovlasis et al., 2006; van Zee, 2000; Warren et al., 2001; Warren & Rosebery, 1996; Woodruff & Meyer, 1997) mark inquiry as an important aspect of science education because it is an opportunity to develop a fuller appreciation and understanding of the processes of science.

The classroom in Mueller's study is typical of many classrooms that aspire to student-centered learning. In Mueller's research, the students' inquiry focused on teacher-designed projects. Under these conditions, there was still an element of teacher control that was exercised in this classroom. Here, the important point is that the students engaged in the scientific activities, and that these included using language in the way that scientists use language. However, inquiry can be conducted in an even less teacher-controlled fashion.

There have been several studies (Roth, 1993; Roth & Bowen, 1995; Roth & Lawless, 2002; Roychoudhury & Roth, 1996) that investigate student-selected open inquiry classrooms. In each of these studies, the elements of student-student and student-teacher communication were the focus for the researchers as they observed the learning of science in these classrooms. In one case, Roth's (1993) study centered on a semester-long physics course that focused on student-selected and designed inquiry projects. In later research, Roth and Bowen (1995) studied student-selected and designed projects for a unit on ecology. As with the physics inquiry in the earlier study (Roth, 1993), the researchers told the students that they should select the subjects of their inquiry projects, design and execute the studies, determine the ways that they would analyze data from the studies and present the to class their findings from their studies. Finally, Roychoudhury and Roth (1996) revisited the events of the 1993 study to examine more broadly the relationships and interactions that were a part of the physics class.

Both the 1993 and 1995 studies employed the cognitive apprenticeship metaphor as a guide for and a means of examining the students' and teachers' activities. In the studies, the teacher/researchers functioned as science masters to the students, who were their science apprentices. This way of viewing learning in the science class is on the based on Lev Vygotsky's (Roth & Bowen, 1995) theory of knowledge. Vygotsky argued that knowledge was ultimately a cultural product, and not a thing possessed by the individual. While an individual might acquire knowledge, that knowledge was forever marked with the elements of the culture from which it was acquired. Further, after acquiring knowledge, as a member of a culture, the individual became part of the cultural repository for that knowledge. As a result, Vygotsky placed a great deal of importance on the role that more knowledgeable individuals from a community or culture play in transmission of knowledge and values to new learners. Vygotsky held that in a classroom or among specialist scientific researchers, knowledge resides in no single individual but in the community. In the scientific community, as in the community of smiths, novices are initiated into the knowledge and culture of the community by appropriate support of more knowledgeable members of the community. This appropriate support is referred to as “scaffolding” (Wood, D. J., Bruner, & Ross, 1976).

Roth and Bowen (1995) view cognitive apprenticeship as having three stages: modeling, scaffolding, and fading. In the first stage, the master models a novel skill for the apprentice, as the apprentice watches and listens to the master's situated explanation. In modeling, the discourse is dominated by the master. Next, the apprentice attempts to reproduce the master's effort as the master scaffolds the apprentice’s efforts by making suggestions to help and clarify the procedure. This help is given as the master discerns a need and at the request of the apprentice. Here the discourse is two-way and less likely to be dominated by the master. The goal of scaffolding is to provide help with what the apprentice cannot yet accomplish on his/her own, but to provide this support in a way that allows the apprentice to reach a level of competence at which the help of the master will no longer be needed. This withdrawal of support by the master is known as “fading”. According to Roth (1993), during this stage, the discourse will be dominated by the ever more competent apprentice. In both studies, Roth (1993) and Roth and Bowen (1995), the authors view the relationship between the apprentice and the master as a linguistic progression, an evolving discourse. This view is in keeping with Vygotsky's (1981) own views on the importance of language and other communication practices to the transmission of knowledge.

Vygotsky's theory of learning was strongly influenced by the philosopher and linguist Bakhtin (1981):

> The word in a language is half somebody else's. It becomes "one's own" when the speaker populates it with his own intentions, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intentions. Prior to this moment of appropriation, the word . . . exists in other people's mouths, in other people's contexts, serving other people's intentions: it is from there that one must take the word, and make it one's own. (pp. 293-294)

Here, Bakhtin is not speaking of a literal "word" as a lexical unit. Instead, he is speaking of language in the broader sense. Bakhtin (1981) continues,

> Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated—over-populated—with the intentions of others. Expropriating it, forcing it to submit to one's own intentions and accents, is a difficult and complicated process. (p. 294)

In this broader sense the term "word" has much in common with Gee's (2005) "Discourse." Bakhtin is describing the process of appropriating a social language, a speech genre, a discourse (Gee, personal communication 2/20/07). For science, this means that at some point the teacher must step out of the way to permit students to practice being scientists otherwise, appropriating the "word" is unlikely (Gallas et al., 1996; Roth, 1993; Roth & Bowen, 1995). This is particularly true of students from marginalized groups (Gallas et al., 1996).

For the purposes of this study, the social language is the language of science, and the tools are the practices, values and physical equipment of science. By analogy, Wertsch and Toma (1991) write that a politician is identifiable as a politician only because he/she acts like a politician. These actions include the use of a particular social language that might include, broadly speaking, a variety of texts including clothing, affiliations with certain groups and their causes, campaign posters, leaflets, fliers, buttons and campaign ads. In much the same way, the apprentice scientist-student cannot become a part of the community of people that do science unless he/she acquires the knowledge of the community. This knowledge includes the use of community's language in its multifarious forms and the proper use of that community's tools.

So it is no surprise that researchers (Arvaja et al., 2002; Jimenez-Aleixandre et al., 2000 ; Roth, 1993; Roth & Lawless, 2002; Warren et al., 2001; Woodruff & Meyer, 1997) report that when inquiry, the activity of practicing scientists, is the focus of science learning, students are more likely to use the language of science, and the reason seems to be that they are doing the activities that scientists do under circumstances that are very similar to the circumstances under which scientists do them.

It is necessary to reiterate that when the phrase "the language of science" is used, the term "language" is being employed in the broadest socio-linguistic sense. Here "the language of science" is being used in terms of Lemke's (1990) "talking science" and Gee's (2005) notion of Science as a capital "D" discourse. Bird (2001) notes that when framed in these terms, an inquiry approach to science teaching and learning need not include talk at all in order to produce the language of science.

*Evidence of Science Discourse in Science Classrooms*

In classes that are student-centered, where inquiry is the focus of the class, how do students talk when they talk like scientists; what is the nature of this talk? How do teachers talk under these circumstances; what is the nature of their talk? The answer to these questions is that the talk in these classrooms is largely dialogic.

According to Driver et al. (2000), dialogic language is multi-voiced. It considers two or more perspectives in the interest of reaching agreement on acceptable claims or courses of action. Driver et al. explain that in science, dialogic language is frequently in the form of argument. However, dialogic argument stands in stark contrast to rhetorical argument. Rhetorical argument relies on rational authority (Driver et al). Frequently, the strength of a rhetorical argument is judged as much on the social position of the authority as on any objective assessment of the argument's factuality.

In the science class, the authority is the teacher, but in scientific undertakings things are different. In dialogic discourse or argument the parties are assumed to have equal authority, and the strength of their arguments is on the basis of empirical testability. If a science classroom functions dialogically, then expecting students to accept what the teacher says without comment or question is unacceptable. Norris'(1997) position is clear.

> To ask of other human beings that they accept and memorize what the science teacher says, without any concern for the meaning and justification of what is said, is to treat those human beings with disrespect and is to show insufficient care for their welfare. It treats them with disrespect because students exist on a moral par with their teachers, and therefore have a right to expect from their teachers reasons for what the teachers wish them to believe. It shows insufficient care for the welfare of students because possessing beliefs that one is unable to justify is poor currency when one needs beliefs that can reliably guide action. (p. 252)

When students do student-centered inquiry, dialogic argument can predominate. Here, dialogic language is used to determine how to proceed with solving problems, how to interpret observations, what inferences should be drawn from observations and what conclusions are appropriate, given the observations. Dialogic argument becomes the basis for student collaboration and can be observed in a wide array of student-centered inquiry activities. In studies by Tao (2001) and Stamovlasis et al. (2006) elements of dialogic argument were present, and formed the basis for collaboration as students worked in dyads to solve conceptual physics problems that were assigned by their teacher. In the study by Stamovlasis, et al. (2006), statistical analysis of the language used by the students showed that the dyads that employed the greatest number of linguistic elements associated with dialogic argument were more successful than their peers in solving the problems. In Tao's study (2001), analysis of transcripts of student negotiations showed that the most successful dyads used elements of dialogic argument to arrive at solutions to the physics problems. In studies that centered on hands-on, student-centered inquiry the use of dialogic argument may also become a key component of student collaboration (Mueller, 2002; Rosebery et al., 1992; Roth, 1993; Roth & Bowen, 1995; Roth & Lawless, 2002; Roth & Lucas, 1996; Roychoudhury & Roth, 1996).

In all of the abovementioned cases, the authors give evidence that dialogic argument is not just a way of talking, but, as Pontecorvo (1993) and Wertsch and Toma (1991) report, it is a thinking tool that drives talk. Binkley (as cited in Driver et al., 2000) wrote,

> The arguer . . . seeks to influence judgment by getting the audience to construct a reckoning supporting the desired judgment, and the arguer does this by supplying the audience with ingredients for the reckoning. When I argue with you, it is as if I should try to get you to make a cake by

> plying you with eggs, flour, sugar and baking powder: in the end, I hope you will do the mixing and the baking. That is why it is that, when your judgment has been influenced by someone's successful arguing, you have the feeling that not only that person, but reason itself, has persuaded you. (p. 292)

Dialogic argument is not just a pattern of speech. It is an important element that regulates the social exchanges that are part of scientific communities (Driver, et al., Mueller, 2002; Toulmin, 1958). It is one of the key elements of Scientific Discourse.

Dialogic argument is not the only feature of scientific communities that is observed when students are involved in student-centered inquiry. In their study of scientists' discourse Gilbert and Mulkay (Gilbert & Mulkay, 1984) reported that when scientists work as a scientific community such as that formed by a research group at a university, they support one another in their efforts and work collaboratively. However, when several smaller groups of scientists convene at professional conferences, or when an individual researcher or group of researchers publishes a paper, each laboratory group will argue for its particular interpretation of data and try to convince other groups of scientists of the validity of its view.

Woodruff and Meyer (1997) did a study of intra- and inter-group discourse. In this study, students worked in small groups to conduct inquiry, but at intervals they would meet as a whole class to discuss their progress and difficulties. This design provided opportunities for collaboration not only at the group level, but at the class level, too. However, as with real-world groups of scientists, the authors noticed that the students behaved very differently when meeting in their small assigned groups and when the groups convened to meet as a whole class. The students formed two different sorts of scientific communities. Following the pattern of scientific communities formed in laboratories, the small groups of students were interested in very similar problems and worked in a collaborative fashion to support one another's work, and, like scientists working in a laboratory, the small groups of students used dialogic language and analogies to illustrate points of view. In general, small groups of scientists and students employ language to resolve conflict and come to a reasoned consensus (Dunbar, 1995 ).

In the Woodruff and Meyer study (1997), when the students groups met as a class, the small groups of students behaved as small communities of scientists to preserve their particular view of a phenomenon and its causes, and to persuade others of the advantages of their group's particular view. Under these conditions, persuasion may take the form of dialogical language, and may focus on strategies to persuade dissenting groups to a particular point of view by convincing presentation. During these interactions individuals may simply chat and use language to build allegiances through purely social means (Gilbert & Mulkay, 1984; Woodruff & Meyer, 1997).

These studies show that when students are engaged by inquiry they frequently use language in the way that scientists use language. Through the uses of language, classrooms may resemble communities of scientists. As with communities of scientists, collaboration promotes the spread of knowledge and certain practices, such as the ways that data is presented, the ways that arguments are conducted and the way equipment is employed in investigations become widespread and codified among members of the community (Roth, 1993; Roth & Bowen, 1995; Roth & Lucas, 1996; Roychoudhury & Roth, 1996; Watson et al., 2004).

### *The Role of Teacher-Talk in Science Inquiry Classrooms*

What happens to teacher-talk in student-centered inquiry classrooms? What is the nature of their communication with their students? If teachers are not the sole authority in a classroom, if teachers are not the providers of knowledge and sole arbiters of disputes, then what is their role in the class, and how does this alter the context of the classroom? The authors of the studies that have focused on student-centered, inquiry-based classrooms report that teachers serve in a support role in these classrooms (Bird, 2001; Dawes, 2004; Eick et al., 2005; Hellermann, Cole, & Zuengler, 2001; Hogan et al., 1999; Mueller, 2002; Roth, 1993; Roth & Bowen, 1995; Roth & Lucas, 1996; Roychoudhury & Roth, 1996; Shepardson & Britsch, 2006). When the teacher moves from the focus of the classroom, a shift in power occurs. In the teacher-centered classroom, the distribution of power within the classroom is very asymmetrical (Rodrigues & Thompson, 2001). In *Talking Science*, Lemke (1990) writes extensively of the teacher's role in the teacher-centered classroom. While he readily acknowledges that the teacher is a representative of others that really hold final authority concerning what takes place in the classroom, he notes that when the classroom is teacher-centered, the teacher determines what counts as knowledge and is the source of that knowledge; the teacher is the model of what someone who knows these things and wields power looks and sounds like; the teacher is the arbiter of disputes; the teacher determines what will be studied, how it will be studied and for what duration it will be studied. One thing seems certain: when the teacher is no longer the central figure of knowledge and power in the science classroom, teachers talk less and differently, while students talk more and differently, too (van Zee, 2000).

Learning activities in science classrooms in the United States are teacher-centered most of the time (Wertsch & Toma 1991). When the classroom becomes more student-centered, the power distribution within the class is altered. The teacher is always the representative of canonical scientific knowledge; however, when students perform inquiry and are given the responsibility of discovery through activities that they perform, the teacher is no longer that sole source of knowledge within the class. When the students' responsibility is extended to designing an experimental activity, to interpreting the data that are collected and determining how those data will be interpreted, they also become arbiters of what counts as knowledge within the community of student-scientists who make up the class (Jimenez-Aleixandre et al., 2000 ; Roseberry, Warren, & Conant, 1992; Roth & Bowen, 1995; Roth & Lucas, 1996; Salyer, 2000). Newton et al. (1999) write, " 'The' answers to 'the' questions become 'their' answers to 'their' questions" (p. 556).

Other authors write of students and their teachers encountering data that neither students nor teachers can interpret, even though the teachers have backgrounds in research in the area of science that they are teaching (Kelly et al., 2000 ; Roth & Bowen, 1995; Roychoudhury & Roth, 1996). In these cases, the teachers report that they become co-investigators with their students. This symmetry of authority is seldom seen in the science classroom, and is virtually impossible when students' hands-on activities are limited to canned confirmatory exercises. As students act to construct their own knowledge and begin to see themselves in the role of scientist, their notion of what a teacher or scientist looks and sounds like begins to turn from the model that might have stood before the class to an image that looks like the student and his or her classmates (Delpit & Dowdy, 2002; Rosebery et al., 1992).

While the teacher may always function as traffic cop and a facilitator/referee in the case of disputes of a social and logistical nature, to the extent that dialogic argumentation or discourse becomes an element of student collaboration, the students themselves become the arbiters of disputes that center on knowledge claims (Driver et al., 2000 ; Duschl & Osborne, 2002; Watson et al., 2004). As a representative of canonical science and scientific practice the teacher serves as a model of scientific practices and scientific attitudes toward the world. Canonical science is an authoritative discourse (Scott et al., 2006). It follows certain rules of argumentation, and a community that follows certain conventions determines what counts as scientific knowledge. Ultimately the science teacher is charged with bringing the student to this canonical scientific knowledge. In a constructivist classroom, the teacher treads a path fraught with obstacles and pitfalls as he/she attempts to fulfill this role.

Hammer (1995) writes of the conflict between traditional approaches to teaching science and the teaching of inquiry science. Regardless of the approach, the teacher is obliged to bring students to canonical scientific knowledge. Hammer (1995) writes that, when teaching through inquiry, teachers must ignore their students' wrong conclusions and poorly designed arguments, but that if students are to view science as something other than a collection of facts, students must nevertheless be allowed the space to state their notions and their reasons for their notions. Otherwise, they will adopt the attitude that "I'm always wrong, so I'm going to shut up!" (Hammer, 1995, p. 415).

Scott, Mortimer, and Aguiar (2006) also recognize the tension that exists between the demands of efficiently bringing students to canonical knowledge and the commitment that teachers may have to constructivist pedagogy. They argue that students cannot be permitted to cast about endlessly in an effort to independently construct these canonical notions. On the other hand, the authors recognize the importance of the notions about the natural world that students bring to school and the contribution of these notions to self-construction of concepts that are aligned with canonical science. Scott et al. (2006) write that the tension is created by the pull of the authoritative elements of science against the dialogic elements of constructivist pedagogy that always allow and encourage different ideas to exist within the science classroom. Through the dialogic elements of the lesson, the student-teacher and student-student talk, the group negotiates an understanding of science concepts. Scott et al. acknowledge the importance of dialogic discourse in the construction of scientific knowledge; the authors argue that "any sequence of science lessons, which has as its learning goal the meaningful understanding of scientific conceptual knowledge, must entail *both* authoritative and dialogic passages” (p. 606).

Scott et al. insist that these seemingly contradictory elements be included in a science lesson. However, an examination of the cognitive apprentice metaphor may resolve this contradiction and any resultant confusion. Although this metaphor may seem to exhibit much of the same tension between univocality and dialogicality that Scott, Mortimer and Aguiar (2006) observed in the classroom discourse in Brazilian high schools and Wertsch and Toma (1991) found in their study of Japanese high schools, cognitive apprenticeship retains its dialogicality at all times. In cognitive apprenticeship, the master is an authoritative figure, but the cognitive apprentice is not passive. In this relationship, there are always two voices present. The apprentice is always in dialogue with the master (Roth, 1993).

In the modeling phase of cognitive apprenticeship, the purpose of the master's performance or utterances is to inform. The master’s performance of the skill has an implied element that asks the apprentice, “Do you see? Do you understand?”(Roth, 1993). The apprentice's scaffolded attempt to reproduce the master's demonstration is also highly dialogic, and becomes a questioning device (Roth, 1993). Even if the apprentice does not utter a single word, the attempt asks for evaluation and instruction from the master, and there is a broader social aspect to the cognitive apprenticeship analogy. There are likely to be several apprentices under a master, and because of this, the efforts of the individual apprentices become fertile ground for learning through dialogue among the apprentices (Roth, 1993). The final move in the dialogue is the master's evaluation of the apprentice's effort. In time, scaffolding is withdrawn and the apprentice becomes more competent. Finally as a master, the now experienced individual becomes part of the wider dialogue with a community of practice. This dialogue between the master and the wider practicing community takes a form that evaluates the new practitioner's technique, level of competence and innovation. Ultimately this dialogue places the practitioner within the social and historical context of the community of practice. In this level of dialogue, the master becomes part of the authoritative discourse that sets the rules of scientific practice and that admits and trains new scientific apprentices.

For those who consider education dialogic, the matters of authority and power have always bedeviled philosophers and practitioners of education (Cohen, 1983; Noddings, 1995). In English, the status of the participants in education is apparent in the very origins of the names. Pupil is from the Middle English *pupille*, meaning a minor ward (Gove, 1986); teacher is from the Middle English *techer*, meaning one who shows or reveals (Gove, 1986). The very fact that some are placed in the roles of teachers and others in the roles of students on the basis of their place within a particular community is testament to this unequal status. Some science education literature argues that inquiry addresses the imbalance of authority in the science classroom through a change in status for students and teachers that is indicated in the way that students and teachers communicate.

*Elements of Inquiry Associated with Science Discourse*

As a result of the outcomes that are possible when it is used, at least in the United States, the student-centered science classroom that uses inquiry as a method of teaching and learning is endorsed in documents such as *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (2000), *National Science Education Standards* (1996), *Benchmarks for Science Literacy, Science for all Americans* (1993) and *Georgia Performance Standards in Science* (GAGPS, 2005). In Chapter 1, these documented goals were connected to what might be called Science Discourse, following Gee's (2001) terminology. Here, "Science Discourse" means the situated language of science that reflects not only the way that language is employed, but also the values and relationships that are characteristic elements of a classroom community that resembles a community of scientists. This being the case, these questions must be posed: Do students in a student-centered classroom always become involved in Science Discourse? Is inquiry a necessary aspect of the student-centered classroom if these gains are to be realized? Finally, if the student-centered science classroom that focuses its activities on inquiry is so desirable, then why is this condition so rare?

Keeping in mind that there are degrees of inquiry and student-centeredness, students in a student-centered classroom do not always become members of the Science Discourse. It does seem clear that there are two conditions which, when present, tend to accompany the development of Science Discourse in a classroom. These two conditions are (1) questions or activities that engage students because they require inquiry and (2) the explicit teaching or modeling of the language habits and values of scientists.

In several studies and theoretical papers, authors present evidence and contend that these two factors are necessary (Duschl & Osborne, 2002; Hogan et al., 1999; Jimenez-Aleixandre et al., 2000; Mercer et al., 2004; Mueller, 2002; Roychoudhury & Roth, 1996; Tao, 2001). Duschl and Osborne (2002) write of the important role that teachers play in modeling and explicitly teaching the language practices of science. The authors state that

> whether it is the scientist working on the creation of new knowledge, the application of well-established theories or a students attempting to comprehend old knowledge, the argumentation is essentially similar--both participants have to construct an argument that justifies the claim that they espouse in the light of evidence that they have at hand (p.56).

According to the above-cited authors the habits and values of dialogic argument that are part of Science Discourse must be explicitly taught.

These authors also recognize that the environment that supports dialogic argumentation is different from what exists in most science classrooms. Describing this state, the authors contend that

> the nature of the power relationship that exists between science teacher and student, and the rhetorical project of the science teacher which seeks to establish the consensual-agreed-scientific-world-view with the student, means that the opportunities for dialog are minimized. (p. 56)

They write that the transformation of the science classroom's atmosphere begins when more than one explanation of a phenomenon is considered. For this transformation to continue, student-student interaction must be fostered, and students must collaborate on solutions. Duschl and Osborne (2002) continue.

> [D]emocratic norms of responsibility and tolerance and the scientific norms for the construction of arguments on the basis of theory and

> evidence must be taught to students. In essence, part of the role of the teacher must be to teach his or her students the social and epistemic ground rules for engaging in productive dialogic discourse. (p. 56)

Students' misperception of the goal of education may prevent the development of Science Discourse. Jimenez- Aleixandre at al. (2000) and Duschl and Osborne (2002), report that the students' views of what is required in a science lesson may stem from past experiences that have failed to make clear that "science is the lesson" and that dialogue with classmates and teachers, along with reflection, are part of doing the science. The authors also report that Science Discourse may not result when the students are assigned a task that does not require dialogic use of language. That is, if the task is one that can be done by an individual, then there is a good chance that students will do the task individually.

Another study that connected Science Discourse to the quality of tasks assigned to science students was done by Mercer et al (1994). His study reports on the quantity and quality of a form of dialogic language that the authors call "Exploratory Talk". Prior to the study, students were trained in the "ground rules" of collaborative talk. The students in the study worked in small groups on computer-based tasks that were designed with different solution structures that depended on what the authors referred to as the "openness" of the software. Software that is "open" has little structure and few pre-arranged outcomes, while problems with "closed" structures have clear and definite solutions or outcomes (Mercer et al., 1994, p. 28). Mercer et al report that "discrete, serial, 'closed' problem-solving tasks generate little extended continuous discussion of any kind" (p. 29). Additionally, the findings of the study show that "the quality of talk is strongly influenced by children's interpretations of the requirements of the activity, and in particular by their awareness of the quality of talk as an aspect of the activity" (Mercer et al., p. 30).

Studies by Watson et al (2004) and Kelly and Chen (1999) provide examples of studies where elements of inquiry were present, but students were not engaged by tasks that required collaboration and inquiry for their solution. In the Watson et al. (2004) study, elementary school students were asked to work in groups and to investigate the strength of paper chains that they constructed. The project was assigned to the students; however, the students were allowed to select an independent variable that was the focus of their group's investigation. In the Kelly and Chen (1999) study high school physics students studied waves. The unit on waves included a variety of teaching and learning methods and activities that are typical of a high school physics class. Students prepared lectures and demonstrations, and participated in discussions, group work, media, laboratory experiments and presentations. The physics unit culminated in a project that required the students to build a musical instrument and write a technical paper on the instrument.

Watson et al (2004) found that there were very few examples of students' use of dialogic arguments or of students' forming a community of learners that functioned as a community of cooperating scientists. The students' talk centered mainly on procedural matters, and how they should do the activity as their teachers expected.

In both studies there were several factors that led to these outcomes. The educational aims of the activities were not made explicit to the students. There was little effort on the part of the teachers to scaffold the students' efforts at collaboration or to explicitly teach them the rules of dialogic language. Additionally, the students followed a pattern that they had successfully employed in numerous previous science activities where inquiry was presented as a series of prescribed procedures. This made the students feel that the activities that were the focus of these studies, like the others that they had done previously, were trivial exercises. The students were, in a sense, doing what Bloome et al. (1989) refer to as "doing the lesson".

Bloome et al. (1989) argue that students “doing the lesson” are engaging in what he refers to as procedural display. Procedural displays are on the basis of the teacher’s and students’ perceptions of what it means to be a student or a teacher in the context of the particular community, school and classroom. Bloome et al. explain that the Socio-Cultural Influences (SCI) in the community in which the school is situated create a school’s context. These influences and the notion of community may be defined from within or from outside the classroom.

For Watson et al. (2004) students’ previous experiences are SCIs that make Scientific Discourse unlikely. Previous experience taught that inquiry is accomplished by a prescribed series of steps that magically produce knowledge, THE SCIENTIFIC METHOD, of which dialogic argumentation is not a part. In addition to the backgrounds of the learners, Watson et al. also cite “the expectation of the local community, expectation of the school management and principal, the social norms established by the local education authority and by national policies” (p. 40) as additional SCIs that influenced the study’s outcome. These SCIs are the narrow definition of inquiry in English national education documents that restrict the range of activities that are used in science education. Additionally, inquiry activities at the national level are assessed through students’ written accounts, and since the written product is the focus of assessment, the teaching and development of aspects of scientific practice other than writing are devalued (Watson et al., p. 41).

In support of these contentions, Watson et al relate that when researchers interviewed the students, the students were asked about their findings. In interviews, students felt that it was necessary to offer support for their conclusions and to argue for their particular interpretations on the basis of the data that they collected. The authors concluded that, in the context of the classroom, the students felt there was no need to make arguments and to give justifications to their teachers or to one another. On the other hand, in the different context created by the interview, the students felt they had to make these arguments and justifications so that the researchers would understand what had transpired during the activities and why their particular conclusions were reached.

In the study by Kelly and Chen (1999) the process of written and oral discourse was also the focus of the study. As in Watson et al. the authors observed very little dialogic argumentation. This was particularly true in the case of the technical paper that the students regarded largely as a procedural display (Kelly & Chen, 1999). Kelly and Chen referred to the students as "performing in the process of studenting, rather than the substantive process of knowledge construction” (1999, p. 909). Since the students were not taught the social practices of science, they did not exhibit them. This paper differs from several others (Driver et al.; Mueller, 2002; Pontecorvo, 1993; Stamovlasis et al., 2006; Tao, 2001; Wertsch & Toma 1991) because it views argumentation in a purely rhetorical form and does not acknowledge the differences between intra-group and inter-group arguments (Gilbert & Mulkay, 1984; Woodruff & Meyer, 1997) that occur in communities of scientists.

A study by Mercer et al. (2004) highlights the importance of explicitly teaching the habits of dialogic argument and the values of Scientific Discourse. In this study there were two groups of students: a treatment group in which students were taught a language program called "Thinking Together" that teaches the language practices needed to work dialogically, and a control group that was not taught the "Thinking Together" program. Through "Thinking Together," students who were in the treatment group were to develop their abilities to use language as a tool for thinking individually and collectively and for enabling them to use language as a tool to effectively study science and math. The rules of "Thinking Together" require that all information in the group is shared, that all members are invited to participate in the discussion, that all opinions and ideas are respected and considered, that everyone must make their ideas clear to other group members, and that challenges and alternatives are made explicit and are negotiated (Mercer et al.).

Mercer et al. (2004) assigned both the treatment and control groups of students identical computer-based problems to solve through inquiry. These inquiry sessions were followed by whole-class discussions and sharing sessions. In the case of the treatment groups, the teachers modeled scientific use of language and made sure that the "Thinking Together" rules were followed. The students from the control groups also participated in discussions following their inquiry tasks.

The results of the study (Mercer et al., 2004) show that there was a large increase in the amount of collaboration in problem-solving and that the collaboration employed scientific use of language among the treatment group students as compared with the controls. The findings from the quantitative portion of this study (Mercer et al.) show that the students who participated in the "Thinking Together" and computer-based problem-solving tasks enjoyed an increase in reasoning as measured by the Raven' s Progressive Matrices Test, a nonverbal test of reasoning, as compared with those in the control group.

As the results of these studies show, inquiry and student-centeredness are not guarantees that Scientific Discourse will result. It appears that two factors are needed to increase the likelihood that scientific language practices and the values embraced by the scientific community will become part of the science classroom. These are tasks that require inquiry and either explicit instruction in the scientific community's language practices, or scaffolding of students attempting these practices, from a skillful teacher.

These factors appear to be necessary, but are they sufficient to insure Scientific Discourse in a science classroom? The answer to this question appears to be "no." The insufficiency of these factors is most apparent when reviewing the literature dealing with science education and marginalized students.

### *Competing Discourses in the Science Classroom*

At this point, I would like to call attention to several concepts from the beginning of Chapter 1. The first is the concept of "D" discourse; the other is The Building Task.

Students and teachers bring their various Discourses to school and into the science classroom. There may be aspects of these Discourses that can be impediments to participation in Science Discourse. Canonical science is an authoritative discourse (Duschl & Osborne, 2002; Hammer, 1995; Mercer et al., 1994; Moje, Collazo, Carrillo, & Marx, 2001; Roth, 1993; Scott, 1998; Scott et al., 2006); its ontological and epistemological commitments are empirical (Hempel, 1966). Its language practices are frequently confrontational, and, at times, science employs familiar words whose meanings change in the scientific context (Itza-Ortiz et al., 2003; Williams, 1998).

Students who come from a variety of backgrounds, such as, conservative faith backgrounds that clash with scientific ontological and epistemological commitments may be marginalized in the science classroom (Aikenhead & Jegede, 1999; Lemke, 1990, 2001). The student from a fundamentalist Christian home where scriptural literalism is taught, may find participation in Science Discourse very difficult, as this participation would call on the student to turn his/her back on Biblical, clerical and parental authority and risk social ostracism (Lemke, 2001). Students who come from language and cultural backgrounds where the patterns of scientific language are unfamiliar or considered impolite may find participation in Science Discourse distasteful or very confusing (Brown, 2004; Brown, 2006; Delpit & Dowdy, 2002; Gutierrez, Baquendano-Lopez, Alvarez, & Chiu, 1999; Lee, 2001; Lee & Fradd, 2003). Even for native English speakers, the special way that science employs familiar vocabulary may be a barrier to learning science (Itza-Ortiz et al., 2003; Williams, 1998). This difficulty is amplified for students who use non-standard dialects of English or who are learning English as they try to understand and learn science (Gallas et al., 1996; Warren et al., 2001; Warren et al., 1996; Westby, Dezale, Fradd, & Lee, 1999 ).

Additionally, the roles of teachers and students in a student-centered classroom that uses inquiry to learn science may be fundamentally different from those that are expected by students from a variety of backgrounds (Aikenhead & Jegede, 1999; Brown, 2004; Lee, 2001; Lee & Fradd, 2003; Lemke, 1990, 2001; Lynch, 2001). These students may come from backgrounds where the teacher is expected to be the authority and the provider of knowledge, and students, rather than constructing knowledge with their classmates, are expected to accept and memorize the teacher's lessons.

One of the most notable examples of teachers helping groups of marginalized students to appropriate Science Discourse can be found in the work of the Chèche Konnen Center. Located in Boston, Massachusetts, The Chèche Konnen Center, which is a school that serves linguistically diverse students, grades K-8, that include Haitian and Latino students. Cultural background is a key component of identity, and one of the key socially situated uses of language is establishing identity. Identities are wrapped up in Discourses. When aspects of various Discourses are incompatible with Science Discourse, it may be difficult or impossible to appropriate Science Discourse.

At Chèche Konnen, the students investigate a variety of science topics in an environment that fosters the creation of a scientific learning community. In this setting, the teachers, who speak Haitian Creole and Spanish, and the students use the language and cultural customs of these groups to construct an understanding of science fact and culture. In Chèche Konnen the students' experiences of culture are considered an asset rather than a source of alienation and deficit. This approach changes learning science from a vocabulary-learning exercise into a valuable way for students to know the world around them. Students in Chèche Konnen are typical of many groups of marginalized students who inhabit two worlds, as they move between their first culture and their new second culture. Students learning science in Chèche Konnen recruit the resources of the first as well as the second culture to construct scientific meanings (Rosebery et al., 1992; Warren et. al., 2001; Warren & Rosebery, 1996).

In Chèche Konnen the focus is always on the students' questions. This permits

> students to work toward goals that are meaningful to them and, often, to the larger community (which can encompass the classroom, the school, or the outside community). In this way, through their own activity, students begin to bridge the gap that separates the school from the culture of the home and community. (Rosebery et al., 1992, p. 63)

An example of this approach is found in a chapter of *Innovations in Learning: New Environments for Education* (1996) called “This Question is Just Too, Too Easy!” by Warren and Rosebery, two of the researchers who have worked with Chèche Konnen. The chapter deals with the construction of standards for confirmation of scientific claims and students’ accountability to those standards in a class of Chèche Konnen science students. Warren and Rosebery (2001) used the robust tradition of rhetorical argumentation in Haitian culture as a foundation on which students could be taught dialogic argumentation. Through a process of scaffolding students’ attempts toward dialogic discourse, the students and teachers began to construct a community within the science classroom that valued scientific evidence and the use of that evidence to support scientific claims (Warren & Rosebery, 1996).

The approach of Chèche Konnen is made even more interesting by the background surrounding Creole languages. Warren et al (2001) relate that Haitian Creole was a language that developed among African slaves who were thrown together on plantations in Haiti with no common language. Haitian Creole vocabulary is based on the French language of the colonial enslavers. The authors also relate that in Haiti, French is the language of education and of the educated (Warren et al.). In Haiti, particularly among the French-speaking upper class, Haitian Creole is viewed as insufficient for the needs of education; it is viewed as Creole languages frequently are, as broken and infantile versions of the colonial language. In their native country, these students and their ancestors endured brutal repression. Their Haitian Creole tongue attests that they were a part of an underclass in their own country.

In this country, they may be free of the overt repression that they endured in their homeland; however, they are part of an underclass here, also. Their ability to escape this underclass status will rest in their ability to master a number of Discourses. The methods that are employed in the Chèche Konnen program are key to this process because the collaborative nature of the school allows the students a measure of choice and control in their educations. In some meaningful ways, these students are owners of their education; they have some control of their lives; they are empowered by their school instead of being controlled by it. Authors such as Lee and Fradd (2003), McKinley (2005) and Rosebery et al (1992) believe that fluency in a Discourse that encourages the systematic assessment of problems, that results in testable suggestions of their causes and effective solutions, is a very empowering step along this way.

Warren et al (2001) extend their conclusions to other marginalized groups whose language and culture may differ from the dominant language or culture. They note that many educators question whether it is realistic to hold students from these backgrounds to the same expectations as students from mainline backgrounds. They respond that to do less is to assume that these students' cultures and native languages do not have the same capacity for creativity, deep thought, refinement of ideas or complex argument that is present in the cultures and languages of students from more affluent homes, where the parents may be better educated.

Likewise, in the science classroom children's questions and their familiar ways of discussing them do not lack complexity, generativity, or precision; rather, they constitute invaluable intellectual resources which can support children as they think about and learn to explain the world scientifically (Warren et al., p. 548). Chèche Konnen and other programs that have been successful in bringing marginalized students into Science Discourse do so, not by viewing these students as linguistically or culturally deficient, but by taking seriously the linguistic and cultural resources that the students bring with them and incorporating them into the practices of a sense-making community (Warren et al.).

*Myths and Powerful Voices*

Important national education documents, such as *Inquiry and the National Science Education Standards* (NRC, 2000) and *Science for All Americans* (AAAS, 1990) and the Georgia State Department of Education Georgia Performance Standards (GPS) for Science (GSDOE, 2005) promote constructivist pedagogy associated with student-centered inquiry as a goal for all science classrooms. However, a number of studies, note how rare these desirable practices are in classrooms in the United States. This section will deal with some reasons for this state of affairs (Driver et al., 2000; Driver et al., 1997; Goodlad, 1984; Graesser et. al., 2002; Lemke, 1990).

An explanation of this condition is found in the research of Tobin and McRobbie (1996). The authors attribute the small number of classes that use inquiry and students-centered approaches to teachers' resistance to change. In their work, the authors examine resistance in "teacher beliefs and different ways that teachers framed knowledge of teaching" (1996, p. 225). In the study,

> [B]eliefs expressed as propositions were examined in relation to beliefs associated with metaphors, images and narratives. . . . [T]hese investigations involved intensive longitudinal studies of individuals and the manner in which they constructed, remembered, reconstructed and applied beliefs as referents to plan and enact a curriculum. (p. 225)

The authors refer to these beliefs as cultural myths about education. By myths Tobin and McRobbie do not mean something that is simply imagined. Rather, they consider myths as powerful cultural shorthand for actions that are deeply imbedded in a culture. In the authors' words,

> Participants know how to act in a given situation because they have lived their lives in a cultural milieu and have adapted their practices to the cultural myths that constrain what happens. Given practices may feel right or may be justified in terms of stories that have their genesis in the "lived lives" of a particular community. (Tobin & McRobbie, 1996, p. 225)

One aspect of Tobin's and McRobbie's (1996) research is a case study of an Australian high school chemistry teacher who set about to change his teaching to an inquiry-based student-centered approach. In the study the authors found that in spite of the teacher's sincere efforts, there was little change in his teaching.

An analysis of the teacher's comments revealed his feeling about teaching practices. He commented,

> I feel that what I'm doing in my classes is what most teachers do and I feel that there must be a hidden reason why it is that this sort of 'bread and butter' type of teaching is most prevalent. I've got a gut feeling that teachers just know by instinct that it's the most efficient way to cover an entire course and to meet all the demands that are placed on students in the most efficient way. (Tobin & McRobbie, 1996, p. 235)

Tobin and McRobbie refer to these "gut feelings" as the Cultural Myths. Specifically these are myths of Transmission of Knowledge, Efficiency, Rigor and Exam Preparation. While a myth cannot be empirically proved true or false, it may nonetheless be a powerful explanation for perceived restraints and actions in education and in this teacher's chemistry class in particular. Tobin and McRobbie (1996) trace the origins of these myths to epistemological beliefs and beliefs concerning apportionment of power.

In the Myth of Knowledge, knowledge is reified as a transmissible entity with the teacher as its source. The Myth of Rigor casts the teacher as the guardian of standards; The Myth of Efficiency places him in control of keeping the class on schedule; while the Myth of Exam Preparation makes him responsible for preparing students for exams. In his view, he is the one who must exercise power over the class. Tobin and McRobbie (1996) note the irony of the situation. The teacher truly wants to alter his teaching practice because he feels that it will ultimately benefit his students; however, he views himself as virtually powerless to change what he regards as inescapable obligations.

Clegg's (1989) discursive analysis of power offers a means to understand the chemistry teacher's difficulties. According to Gilbert and Low (1994),

> Clegg argues that power is not a property held by persons as some form of episodic agency would have it, but that power is relational, and is the product of structured sets of relations among people, relations that are not attributable to or created by particular people, but are more historically, institutionally and discursively produced. (p. 7)

Clegg characterizes power as occurring at three levels. The first level is the episodic level. At this level, specific agents and events operate through relations and circumstances. Circumstances may include resources, means of action, influence, forms of control, along with outcomes and consequences in particular events (Gilbert, R. & Low, 1994).

The second level of power is exerted through social integration that establishes rules of practice, meaning, and membership, and in so doing constructs dispositional power. Power through social integration is manifest in legal and administrative procedures, the meanings through which practices are articulated and justified, the delineation and construction of groups, alliances and status and the contests over these rules of meaning and membership (Gilbert, R. & Low, 1994).

The final level of power is found in means of system integration. Examples of system integration are systems of administration, techniques of control and dissemination of information, and relations between forms of production, disciplinary expertise, and legal and political process (Gilbert, R. & Low, 1994).

Gilbert's and Low's (1994) adoption of Clegg's view may be employed to explain the teacher's predicament in Tobbin and McRobbie (1996). The teacher has power in his classroom because he is an agent that controls resources, means of action, influence, forms of control, along with outcomes and consequences in particular events. However, his feelings of powerlessness are caused by the exercise of power in the form of social integration that acts through constraints imposed by administrative agencies, such as boards of education and curriculum monitors. These administrative organizations construct dispositional power through establishing rules of practice, meaning, and membership.

In the case of the teacher's powerlessness to step away from standards of rigor, examination questions, forms of examination and admission of students to tertiary institutions, power is being exercised at the level of system integration.

The inclusion of Clegg's analysis of power (1989) is useful and appropriate to this literature review because he views power not as a thing individuals or institutions possess, but as *relational* and *discursive* between individuals and institutions. The study that is proposed in this prospectus centers on the way that language is used to enact Discourses in science learning. Discourses are one way that more powerful groups in society can influence less powerful groups (Gee, 2005, p. 81). This view of power also fits with the notion of internal and external sociocultural influences that shape the teachers', students' and community's notion of what science is and how it might best be taught (Watson et al., 2004).

Clegg's view also fits well with the contention that there are many voices in the classroom other than those of students and their teachers. These other voices belong, not to individuals, but to institutions that are shaping the context of the classroom and are, at times, standing in opposition to Science Discourse. Newton et al. (1999) see the influences of these other voices, and the Discourses they urge, in the relationship that currently exists between education and industry. This relationship has transformed education into a marketized undertaking. Newton et al. maintain that education is no longer part of a broader social alliance, but now has become an alliance with business interests. This relationship places importance on education because of its economic utility and its ability to bring added economic value to citizens. The authors (Newton et al.) see the accountability movement in education as an outcome of the hegemony of business over the world. This hegemony has forced the educational establishment to see students and teachers not as human beings, but as means of production for a valuable commodity, good test scores. So it seems that the science classroom is a forum for broad discursive practices that include voices from both inside and outside the classroom. These broad discursive practices are what James Gee (2005) refers to as "C" Conversations.

Gee (2005) defines Conversations as those discussions or debates that are prominent in a society or in particular areas of a society. They are so clear and so prevalent that everyone who is fluent in the broader social language of a society knows both sides of the Conversation, and who in the society will be attracted to a particular side of the Conversation. Conversations are creations of the media; however, their existence in the media is really the result of "myriad of interactional events taking place among specific people at specific times and places" (Gee 2005, p 49). Examples of Conversations in our society are Ebonics, Feminism, Affirmative Action, Abortion and Evolution/Intelligent Design. Conversations are always about beliefs and values, and these values and beliefs are always representative of disputes between what Gee refers to as Discourses.

The school is an institution that is a focus of a number of Conversations. For anyone who views the school, its activities and occupants, in Gee's terms, the social cacophony that results from the dissonant voices in these Conversations is deafening. The principal Conversation that shapes schools and science classes today is between a Modernist neo-Conservative Worldview and Liberal Post-Modernist Worldview Discourses. The friction generated between these two Discourses is familiar to anyone who follows educational policy debates, or for that matter, experiences the day-to-day sturm und drang that buffets teachers, students and administrators in a typical public school. The science classroom is particularly affected by these Conversations. The influences of these Conversations shape the social and linguistic context of the science classroom and constitute the very powerful voices that all too often drown out those of students and teachers.

## Summary

This review of literature has established that science is a socially situated activity that employs language in very particular ways. It has also established that when students engage in inquiry in classrooms that are student-centered, the students and their teachers form different sorts of relationships with one another, and use language differently from the way they do in classrooms that are not student-centered. Under these conditions, these relationships and this use of language are very similar in quality and function to the relationships and language used in scientific communities. Additionally, this review highlights examples from the science education literature that show that the relationships and language observed in student-centered science classrooms are, in part, the result of shifts in power between students and teachers. These examples from the literature further associate this shift in power with an environment where knowledge is viewed as a thing that is socially constructed, rather than an entity that is transmitted from those who have it to those who do not. This review has also pointed to reasons why this view of knowledge and the results that may accompany it are so highly favored. Finally, there are examples from the science education literature that offer socially situated reasons for why these favored results are so rarely achieved.

Despite the breadth of this review, there are several gaps. Firstly, none of the studies in this review focused on *how students and teachers enact Discourses* in the science-learning. Secondly, none of the studies focuses on *how pedagogical activities* facilitate the discourses enacted by students and teachers. These questions were the focus of this study. Finally, none of these studies applies discourse analysis to these questions or similar questions. The results from the proposed investigation may help to fill these gaps in the science education literature.

The socio-linguistic basis that underpins both Lemke's "talking science" and Gee's notion of Discourse forms a suitable theoretical framework for this study and makes my research approach unique. Gee's version of discourse analysis (Gee, 2005) comes out of his work in language and literacy (Gee, 2001). Because the study will focused, in part, on the activity of students engaged in the acquisition of a scientific language and literacy (Itza-Ortiz et al., 2003; Lemke, 1990; Moje et al., 2001; Williams, 1998), Gee's (2005) version of discourse analysis is an appropriate analytical framework for the this study, and its use in the study is unique.

# CHAPTER 3

# METHODOLOGY

In this study, I focused on the use of language in an extracurricular science-learning environment, a robotics team. The study examined student language in the context of student-centered inquiry as an approach to science education. The NRC documents, *National Science Education Standards* (1996) and *Inquiry and the National Science Education Standards* (2000), recommend that science education offer students the opportunity to engage in the activities in which scientists engage. The authors of these documents also argue that students must have opportunities to *do the activities of scientists* and must be *taught the language and values of scientists* (NRC, 1996, 2000). Further, the science education literature documents the rarity of these practices in science classrooms in the United States.

The abovementioned recommendations call for a reorientation of science teaching and learning that will result in teachers' and students' adopting very different roles from those that they enact in the traditional teacher-centered science classroom. According to Gee, (2004a, 2005) these classroom roles are socially constructed, because particular language is bound to particular activities; Gee (2001, 2004b, 2005) refers to roles so constructed as "Discourses". The goal of the study is to show how students and teachers use language to construct their Discourses in the context of student-centered inquiry teaching.

When language that is situated in use is the focus of research, discourse analysis is an appropriate choice of methodologies (Adger, 2003; Gee, 2005; Rogers, 2004; Wodak, 2001; Wood & Kroger, 2000). The various approaches to discourse analyses are both a qualitative interdisciplinary methodological approach and a set of methods that are employed in analyzing linguistic data collected in naturalistic settings (Gee, 2005; Rogers, 2004; Wodak, 2001; Wood & Kroger, 2000).

## Choice of Methodology

Educational research is dominated by methodologies that are either positivist or non-positivist in approach (Crotty, 1998). It is the distinction between these orientations and the epistemological and theoretical differences that undergird them, that must guide researchers' choice of methodology. In the end, these also govern the types of data that are collected and the ways those data are analyzed (Bogden & Biklen, 2003; Crotty, 1998; LeCompte & Schensul, 1999).

Positivism is a term that is generally associated with August Comte (Parker, 1989 in Schwandt, 2001, p. 28) and has come to be associated with the "scientific method" (Bogden & Biklen, 2003). As Comte applied positivism to sociology and, by extension, to education as an aspect of society, a positivist would seek to uncover "the laws that govern the development of society" (Schwandt, 2001, p. 399). The assumption that positivists make is that reality is objectively knowable, "stable, observable and measurable" (Merriam, 1998, p. 4). Implicit in this approach is the notion that reality can be discerned from observations and measurements of isolated phenomena made by a detached objective researcher.

Non-positivist educational research emerges out of constructionist or subjectivist philosophy. These epistemologies hold that knowledge is not reliable and unchangeable (Philips & Burbules, 2000); that the knower and the known are not separable. As a result, all research questions and research results are inseparably tied to contextual elements that influence both the knower and the known, including class, social race, ethnicity, gender, age, individual and group history (LeCompte & Schensul, 1999). These approaches to educational research provide holistic and rich descriptions of the way that contexts shape students' and teachers' lives and the ways in which these lives shape those same contexts (Bogden & Biklen, 2003; Lincoln & Guba, 1985). They also lead to different truth claims and in some cases reject notions of validity or generalizability (Crotty, 1998).

One of the non-positivist epistemologies is constructivism (Bogden & Biklen, 2003; Crotty, 1998). Crotty (1998) defines constructivism as

> the view that *all knowledge, and therefore all meaningful reality as such, is contingent on human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context.* [author's emphasis] (p. 42).

The primary aspect of 'social context' to which Crotty refers arises in the institutions that human beings inhabit as members of cultures, and the meanings that they generate through their interactions with those institutions. Crotty (1998) calls this social variant of constructivist epistemology Social Constructionism. Language and symbol systems are important tools of social construction (Crotty, 1998; Gee, 2001, 2004a, 2004b; Wodak, 2001; Wood & Kroger, 2000) through which human beings are shaped and through which they shape social institutions. It is in this aspect of Social Constructionism, particularly as articulated by Ernesto Lacau (Wodak, 2001), that CDA is epistemologically grounded.

Two theories that inform CDA are neo-Marxist Critical Theory and Poststructuralism. Neo-Marxists Habermas and Freire developed theories of power and liberation that hinged on the ways that language is controlled by social institutions (Crotty, 1998). Poststructuralists such as Foucault (Crotty, 1998; Gee, 2004a) and Bakhtin (Gee, 2004a; Wodak, 2001) find the meaning of words in the words' relationship to one another without reference to non-linguistic forms. For these and other poststructuralists, the meaning of language is situated in the societal relationships to which it gives life. To the extent that these societal relationships apportion power, Poststructuralism is a critical theory.

As noted in Chapter One, CDA is both a theory and a methodology that is associated with a set of assumptions. Fairclough and Wodak (1997) have listed eight:

- CDA addresses social problems
- Power relations are discursive
- Discourse constitutes society and culture
- Discourse does ideological work
- Discourse is historical
- A sociocognitive approach is needed to understand how relations between texts and society are mediated
- Discourse analysis is interpretive and explanatory and uses a systematic methodology
- CDA is a socially committed scientific paradigm

Embedded in these assumptions is that *language is action* and that *language constitutes reality*; it is not an expression of some pre-existing or underlying discourse-independent reality. In keeping with the Constructivist and Poststructuralist traditions from which it is drawn, CDA regards language as an *objective reality* to which qualitative methods may be applied and from which the analyst constructs a *subjective interpretation* of a discursively constructed reality (Crotty, 1998; Gee, 2005; Rogers, 2004; Wood & Kroger, 2000).

## Study Setting and Context Setting

### *Participants*

The following study focused on a group of high school students, three of their teachers and two professional engineers who participated in an extracurricular robotics club that built a robot for the 2008 First Robotics Challenge (FRC). The students attended and the teachers taught at one of two high schools located in the same suburban metro Atlanta county school system. The study was conducted at the 2008 FIRST Robotics Challenge competition that was held at the Gwinnett Center in suburban metro Atlanta, Georgia, from March 12-14, 2008, and interviews were conducted at one of the two high schools.

The robotics team was an extracurricular activity. As such, participation was completely voluntary and open to all students. The goal of the robotics team was to build a robot that would compete in the FRC that occurs every spring. The nature of the competitive task, the budget of the robotics team, and the creativity and expertise of the students and their mentors determined the design of the robot. The organization that sponsors the competition is FIRST, a nonprofit organization whose mission is to design "accessible, innovative programs that build not only science and technology skills and interests, but also self-confidence, leadership, and life skills" (FIRST, 2007).

The choice of this learning environment for study represented both a purposeful and convenience sample. Purposeful sampling is sampling done with an eye toward the expansion of a developing theory. Chapter Two highlights results from studies and contentions from theoretical writings that suggest that students and teachers are required to take different roles as they do different sorts of learning activities. Some of these writings point out differences in the ways that language is used during different sorts of science learning activities. This study aimed to extend this line of research and expand the theory that underpins it in two ways. Firstly, the study made use of CDA to analyze linguistic data that were collected in a setting where student-centered inquiry learning activities were conducted. Secondly, the study expanded this theoretical line by using Gee's theoretical construct, Discourse, to view the reflexive role played by learning context and language. This sample was purposeful because the study's circumstances provided opportunities to study the phenomena that were the focus of this study.

In the teacher-centered classroom, the teacher has control over the content that will be taught, the instructional mode and role of the teacher, the activities that students will do, the products that will be made by students in the course of the activity, and how the products and student learning will be assessed. Student-centered learning activities include a continuum of activities. In other words, learning activities may be more or less student-centered. However, student-centered learning activities require students to take a significant and active role in determining some or all of the factors that comprise a learning activity. Inquiry activities also include a continuum of learning activities and, except in their most structured form, inquiry activities are student-centered (See Appendix B) (Martin-Hansen, 2002). Inquiry activities require students to engage in many of the activities that scientists do (Martin-Hansen, 2002).

For a number of reasons that have already been mentioned, the robotics team offered an unusual context to observe teachers and students engaged in learning science. It offered an opportunity to observe teachers and students in an environment where the *primary* mode of learning was student-centered rather than teacher-centered. As noted in the key education documents that inform this study (NRC, 1996, 2000), student-centered inquiry pedagogy is rare in the United States. In the subject activity, students designed and constructed the robot that they entered in the competition. To this end, the students placed themselves in one of four units within the robotics team. One unit produced the mechanical design, another produced the computer interface for the robot, another handled the graphic design for the team's promotion and public relations, and the remaining unit handled logistics and coordinated the activities of the various units. Students were free to move among these units. Certified science teachers and practicing engineers acting as mentors supported the students in their tasks, but within the constraints of budget and the team's expertise, the students were in charge of every aspect of the project. This arrangement met the demands of an open student-inquiry (Martin-Hansen, 2002).

This sample is also a convenience sample. Since the FRC was held during a relatively short period, and the robotics team met after school hours at HS1, where I am a science teacher, the students and mentors were at hand; this sample eliminated logistical complications that could have placed the study beyond the time and material resources that were available to the researcher. While all the teachers and the two engineer advisors agreed to participate in the study, the availability of student participants for study was limited by parent permission and student willingness to participate in the study.

The two high schools, HS1 and HS2, are very similar. While HS1 was a relatively new school that opened in 2006, HS2 opened in 1990 and is more established. During the 2007-2008 school year, 1025 students in ninth through eleventh grades attended HS1. 1704 students in grades 9-12 attended HS2. Both schools collected demographic data when students register with the schools' guidance offices, and these data showed that the schools were demographically similar. The ethnic makeup of HS1 was 92% White, 3% Hispanic, 3% African American, 1.5% multiracial, and less than 1% Asian and Native American. The ethnic make up of HS2 was 84% White, 7.9% Hispanic, 5.2% African-American, 1.3% multiracial, 1.3% Asian, and less than 1% Native American. The schools' districts are middle-class with both schools providing 14 % of students with free or reduced-price lunch.

At the beginning of the 2008 season 35 students attended the first FRC introductory and organizational meeting. At the time of the competition 30 students were participating in the program, 20 were male and ten were female. The make-up of the robotics team reflects the low diversity of the two schools. Two students are Asian. All of the other students in the program are from European backgrounds and are classified as White by the Cherokee County Schools Demographic Profile.

Three certified science teachers sponsored the robotics team and served as faculty mentors. All three were sponsors of the joint robotics team from HS1 and HS2 in 2007. This team won the "Best Rookie Team" in the Peachtree Regional FRC and qualified for the national competition that was held in Atlanta, Georgia. At nationals the team enjoyed some success, but did not win any awards.

One faculty mentor is a male teacher who is beginning his second year in the county system. He is a veteran science teacher with 32 years' experience, and holds national certification and a master's degree in science education. He has been a sponsor of robotics teams for 7 years. The other sponsors are female. One has been teaching in the county system for two years. She is a veteran science teacher with 11 years' experience, and holds a master's degree in science education. The last certified sponsor has been teaching in the county system for three years. She is a veteran teacher with eight years' experience, and holds a bachelor's of engineering degree in nuclear engineering and a masters of arts in teaching science. The engineers that volunteered to work as mentors with the team are not certified teachers. Both are licensed mechanical engineers with master's of engineering degrees. Each was married to one of the female robotics team sponsors. Student team members' profiles are in Appendix A.

*Study Setting and Context*

This study consisted of two phases, the first of which was a field phase wherein data collection was conducted at the FRC competition, which was held at the Gwinnett Center in suburban metro Atlanta, Georgia, on March 12-14, 2008. The second consisted of interviews that were conducted at the two high schools in the eight-week period after the competition.

For Inspiration and Recognition of Science and Technology, "FIRST", was founded in 1989 by noted physicist and inventor, Dean Kamen. The goal of FIRST is "to create a world where science and technology are celebrated…where young people dream of becoming science and technology heroes" (FIRST, 2009).

The inaugural FRC was held in 1992 in a New Hampshire high school gym. Twenty-eight teams competed. In 2008, 150,000 students participated in the FRC. One hundred-twenty teams participated in the 2008 national championship that was held in the Georgia Dome in Atlanta, Georgia (FIRST, 2008).

To understand the context of FRC it might be helpful to understand the organization's intentions, as evidenced in a statement made by Richard Bodor, Senior Mentor, FIRST, Atlanta, at an organizational meeting on the evening of April 1, 2008, at Southern Polytechnic Institute. In his brief comments, Bodor said,

> FIRST intentionally structures the Robot Challenge so that it will introduce students to the realities of real-world science and engineering. They and their mentors are confronted by too little time, too little money, and their intellect is stretched by the demands of the project.

An FRC season begins officially with Kickoff, an internationally televised event that reminds the FRC faithful of FIRST's goals and introduces the FRC game for the new season. Prior to Kickoff, the team, Wild About Robotics (W.A.R.), met several times to begin organizing. At the three preseason organizational meetings, mentors polled team members about what jobs they thought they might want to do during the season, the level of time each was willing to commit, and whether their families might be willing to provide evening meals during the build season. At these meetings there was generally some sort of robotics activity, such as practice programming small robots that use Texas Instruments TI-84 Calculators as a control interface. During this preseason period, W.A.R. also made a field trip to a local medical facility to try their hands at a surgical robotics system.

The preseason is also the period when the promotion group began writing grant proposals for the 2009 season. Grants are important because the FRC is an expensive undertaking, and neither high school is able to guarantee funding for the robotics team. Each season the team needs to cover the $6,000 minimum cost for the robot kit and the entry to the regional competition. Should a team qualify for the national competition, FRC becomes an even more expensive proposition because of the $5000$^{00}$ entry fee for nationals and additional travel expenses. In addition, the team needs to acquire funds to cover the cost of additional robot components that might not be in the kit, team promotion, and hotel and meal costs for the team during the competition. For the 2008 season, W.A.R. won a NASA grant of $8,000 and $1500 from Women in Technology. The two high schools defrayed the cost of meals and hotel rooms for the regional competition.

The 2008 FRC began, as it does every year, on the first Saturday of January (1/05/08) with the annual Kickoff that was shown on the NASA Television Network from New Haven, Connecticut, where FIRST is headquartered. W.A.R. viewed the Kickoff from a local sports bar near both of the high schools in Freehome, Georgia.

During the Kickoff, Dean Kamen, the organization's founder, and Woodie Flowers, chairman of the FIRST Advisory Board, addressed the live and television audiences. Following these opening comments, the 2008 season's game, FIRST Overdrive, was announced; an outline of the rules for the game and an animated simulation of the game were presented. The end of Kickoff marked the beginning of the frenetic build period, that ended six weeks later with the shipping of the robot to the competition site.

After Kickoff, teams in the Atlanta area converged on the Ferst Center for the Arts at Georgia Institute of Technology. Here they picked up the robot kits that FIRST offered for building the robot. These kits contained a variety of components, including various computer interfaces, digital and analog sensors, and various structural and drive train elements.

Rookie teams generally limit themselves to the kit parts in building their first robot. More experienced teams generally spend a great deal of money purchasing lighter-weight structural elements to reduce the weight of their robots. Also, these teams generally buy additional components so that they will be able to build two robots, a prototype robot and a competition robot. The competition robot is shipped, and the prototype is retained by the team for practice and fine-tuning of various systems.

After the Kickoff, W.A.R. convened at HS1. During this time, the team discussed organizational issues, and student team members volunteered for the various functions to be carried out by the divisions of the team. After this there was a brainstorming session that lasted from about 2:00 PM to 6:00 PM. During this session, team members proposed and discussed design ideas for the robo, while another group pored over the details of a lengthy rules document that became available on the FIRST website at the close of Kickoff. At the close of the meeting, captains of each team group were elected, proposals were made for a production timeline, and the timeline was set.

After this first organizational meeting, there were weekly organizational meetings during which the captains of the different team groups and the mentors met to discuss progress and review the production timeline. After these meetings, the captains returned to their groups and apprised them of decisions that had been made.

During The Build, the frantic six-week period during which FIRST teams design and build their robots, the W.A.R. build team worked out of an unused classroom at HS1.

The other segments of the team worked out of the classrooms of the two faculty mentors who taught at HS1. Team captains maintained a sign-in sheet for their group. The hours recorded on the sign-in sheets were used to determine the team members who attended the regional competition in March.

The build team, the group that actually built the robot, was formally composed of 13 students from the two high schools; an engineer, Scott Bruce; and faculty mentor George Mitchell. For practical reasons such as the availability of tools and space, it was impossible for all 13 students to work on the robot at the same time, and so the number of student members working at any one time varied over the course of The Build. The students participating on the build team varied over the course of the season as homework, family obligations and changing interests intervened. No female team members volunteered for the build team, but a few worked from time to time on the robot. Some members of the build team met every afternoon from about 4:00 PM until as late as 10:00 PM during the week and from 11:00 AM until 3:00-4:00 PM on Saturdays. Because of the availability of transportation, particularly for younger team members who did not drive, the ability to attend and the hours worked by student members varied. Of the W.A.R. team's groups, the build team put in the greatest number of hours.

The design team was formally composed of 6 student team members and an engineer, Brian Pacelli. There were five male students and one female student who volunteered for the design team. This group met in the room of faculty mentor, George Mitchell. The design team met on Mondays, Wednesdays and Saturdays for two or three hours at a time. As with the build team, not all of the design team worked at the same time, and several of the design team also worked with the build team. At the post-Kickoff organizational meeting a rough plan for the robot was agreed on, and the design team was asked to submit drawings from which the build team would the robot. In fact, the process was a bit more ad hoc, with the robot being more of an on-the-fly adaptation of the original design and the subsequent updates of that design by the design team. Drawings of the robot were produced by the design team with AutoCAD, a computer-aided design program.

The promotions and logistics team were a group of 11 students and two faculty mentors, Elizabeth Bruce and Lenore Pacelli. All of the members of the logistics and promotions team members were female. The logistics and promotions functions were combined because the demand for logistics or promotion varied so greatly over the course of the season. The promotion function involved grant writing, writing all team correspondence, website design, uniform design, pit area decoration and choosing swag items (promotional trinkets that are distributed at the competition to other teams). The logistics function included all ordering, paying team bills, keeping the team ledger, planning and distributing schedules of meetings, arranging the shipping of the robot, arranging for hotel rooms and meals for competition and arranging team transportation to and from events. The promotions and logistics teams met, on average, for two or three hours after school, as needed. The members of these two teams sometimes participated in building the robot.

*Competition setting.*

The FRC competition was held at the Gwinnett Center in suburban metro Atlanta, Georgia, on March 12-14, 2008. The Gwinnett Center is a large modern convention center. The competition was held in a large space about 300 ft long by about 150 ft wide.

The exposed plumbing and ductwork provided a ceiling about 40 ft high. This area was partitioned from ceiling to floor into two sections. The larger of the two sections was the competition area, a stadium, where the field of play was located at the bottom of a bowl-shaped structure about 200 ft long and about 150 ft wide, with total seating for approximately 1200 arranged in a tiered fashion along either side of the longer dimension. Away from the field of play the competition area was dimly lit. The field of play was illuminated from above by extremely bright lighting. In addition to being very brightly lit, the competition area was filled with very loud nonstop music: rock 'n roll, hip hop, R&B and Country by a large sound system.

The remaining area of the large space, on the other side of the partition from the competition area, was reserved for operational activities. In this brightly lit space were pit areas for each of the 42 teams in the Peachtree Regional Competition. The pits were arranged in rows with wide aisles between for the efficient movement of the robots into and out of the pit area. The pits were 10 ft by 12 ft spaces that were bounded by barriers designed by each team. The W.A.R. team's pit area was decorated in a military camouflage theme, with PVC pipe frame draped with camouflage-type artillery netting. The W.A.R. name banner and flag were prominently displayed at the front of the W.A.R. pit. The din in this area was almost as loud as that in the competition area. The music from the competition area was easily audible in the operations area, and the noise of power tools, the several hundred competitors and their visitors made for an extremely noisy environment.

The remainder of the operational area included judges' area, with tables and public address system, scales for certifying robot weights, and "the cage", a rectangular enclosure used to certify the dimensions for the robots. This space also included a practice area with one half of a of a regulation field of play, a large electronic sign board for announcements and a help desk where diagnostic equipment was available for testing electronic components.

In 2008, 15 student team members, an engineering mentor and four faculty mentors of W.A.R. attended the Peachtree Regional FRC. Of these, 6 student team members were female and nine were male. Seven student team members were from HS1, while eight were from HS2. Two faculty mentors, one male and one female taught at HS1, while two faculty mentors, one male and one female, taught at HS2.

The students who attended the competition were selected on the basis of the number of hours that they worked with their particular group during The Build season. Two students from both HS1 and HS 2 qualified to attend but were unable to do so because of family commitments.

The students attending the competition included some students from the build team, design team, logistics team or promotions team. At competition, there were several special positions that did not exist during The Build. For example there were two qualified positions, robot driver and coach. The two students holding these positions had to win a competition with other team members for these jobs. The driver’s job was to drive the robot. The coach’s job was to serve as an extra set of eyes for the driver and to operate the robot’s other systems, such as the lifting arms and drive train sensors. Both the driver and the coach were responsible for implementing the tactics that were agreed to by the teams in an alliance during a particular round of the competition.

During the rounds of competition, each team was permitted a RoboCoach. The RoboCoaches' job was to signal the robot with an infrared device (W.A.R. used a television remote control) during the Teleoperated phase of the competition. Two of the female student team members volunteered for this position, and alternated with one another during the competition.

Another position peculiar to the competition was Safety Captain. The Safety Captain was in charge of making sure that the pit work area was safe by seeing to proper installation of electric devices, securing electric cords so that they did not constitute a tripping hazard, keeping walkways and common areas near the pit clear of obstructions, maintaining a file of hazardous materials documentation, and insuring that all team members and mentors working in the operations area wore eye protection.

A third position that did not exist during the Build was Scout. There were six full-time Scouts, but during the competition, anyone with a free moment became a Scout. During practice and competitive rounds, Scouts were responsible for observing and rating other team's robots. The FIRST organization produced a rating sheet for Scouts to record their impressions of the other teams robots. Between rounds, Scouts were responsible for going to the pit areas of other teams to gather intelligence concerning their robots and to promote the virtues of the W.A.R. robot.

One of the most important functions during competition was pit crew member. The pit crew consisted of the engineering mentor and the driver and coach. At times, other members of the team worked in the pit for short periods of time when heavy lifting was required, but the small area of the pit and the size of the robot made it impractical for more than two or three people to work in the pit at any one time. The pit crew did repairs to the robot between rounds. These repairs included structural modifications and repairing mechanical, electrical, and software failures. During the competition, the promotions and logistics functions remained more or less unchanged. At the competition, both groups were responsible for setting up the area, and promotions concentrated on handing out swag to other teams and promoting the capabilities of the W.A.R. robot. These students also worked with the faculty mentors to arrange lunches to be eaten on-site during the competition. Three students volunteered for these functions, but students from other groups helped as the need arose.

During the competition, the faculty mentors did a great deal of supervision, and were always in the stands cheering for the team. They worked with the student team members in their functions. They drove students back and forth from the competition to the hotel and from the competition venue to various offsite activities. They ran errands to buy replacement components for the robot.

The typical competition day began at 6:00 AM in the hotel breakfast room. There the team assembled and ate breakfast, while discussing the plans for the day's activities. At 7:30 AM, the team assembled to travel to the competition venue. After arriving at the Gwinnett Center, the team deployed. The pit crew went to inspect the robot, check battery levels, and run systems checks before the first competition rounds. The rest of the team began to move about the operations area talking with members of other teams, sharing successes and horror stories from the previous day and trying to determine the state of the robots for the day's alliances. The first rounds of competition began at 9:30 AM. with matches coming at the rate of one every 30 minutes. Each day, the logistics group would arrange times and places with the sponsoring business (IBM, Siemens and

General Electric provided lunches and snacks for W.A.R.) provided lunch or snacks for a group of teams that included W.A.R. and several other teams. At mid-day there was a pause in the competition, and the teams met in clusters on the grounds of the competition venue for lunch. After the mid-day break competition resumed at 1:30 PM, and matches continued until some time around 9:30 PM, depending on the progress of the matches that day.

*The game: FIRST Overdrive.*

The field of play was a 54-ft by 27-ft track divided lengthwise by a fence into a Red side and a Blue side. Six-foot six-inch racks called overpasses crossed above the central fence and divided the field of play across its narrow dimension, marking the Red Alliance and Blue Alliance finish lines.

In the 2008 game, FIRST Overdrive, two three-team alliances of robots raced around the track in a counter clockwise direction knocking down 40-inch inflated Trackballs from the overpasses, and moving them around the track either by passing them over or under the overpass. Extra points were scored by robots positioning the Trackballs back on the overpass before the end of the 2-minute and 15-second match.

The game was made up of two scoring periods. The first 15 seconds of play was the Hybrid period, in which robots were completely autonomous or could receive digital signals sent by team Robocoaches stationed at the corners of the track. The final two minutes of play was a Teleoperated period. At this time, robots were radio-controlled by team operators standing at either end of the field, in either the Blue Alliance or Red Alliance areas that were located at opposite ends of the field of play.

Teams working together in an alliance attempted to develop a strategy for a match based on a set of tactics that suited the capabilities of the teams' robots. For W.A.R. these arrangements were made by the team's drivers and coach prior to the match on the basis of the head scout's report on the other teams' robots. Without going into too much detail about the scoring of the game FIRST Overdrive, robots might be classified by their capabilities as rabbits, herders or hurdlers. Rabbits were fast maneuverable robots that could score points by doing laps quickly and crossing back and forth across the center line of the track. Herders were able to push the large red or blue fabric-covered track balls along the track and score by crossing either their alliance's line or the finish line. Hurdlers were able to score by knocking balls off of the overpasses and then lifting them up and back over the overpass to score or, to score even more points, replace the designated alliance's color track ball (blue ball for Blue Alliance) on to the overpass above the alliance's line.

So, in a match, the Blue alliance's strategy might be to keep track balls away from a good Red Alliance hurdler by having an effective Blue Alliance herder push balls away from the Red Alliance hurdler and preventing it from scoring, while scoring points for the Blue Alliance by pushing the track ball around the track and across the track lines. A Blue Alliance rabbit might impede and harry a Red Alliance herder by simply running in front of it and getting in the way keeping it from pushing balls across the track lines and providing track balls to the Red Alliance hurdler.

For offense, the Blue Alliance might plan to have its hurdler knock down a ball during the teleoperated phase of the match, gather track balls and try to hurdle these, while the Blue alliance herder provided additional track balls for the Blue hurdler to either hurdle or place on the overpass. This scenario is an ideal match because each alliance has one of each type of robot that is functioning as designed. W.A.R., whose robot was a fine rabbit and a decent herder, was sometimes paired with two other rabbits. In these situations, the options for strategy and tactics were not as varied and the chances for the alliance's success are not as robust.

At the beginning of each round of competition the driver and coach of the six teams, three forming the Blue alliance and three forming the Red Alliance, moved to the appropriate end of the field of play and set up the radio control systems by plugging into the control console, while the pit crews positioned the robots in their starting areas. The Robocoaches moved to their positions at the corners of the field of play.

After all the robots and the crews were in place, the Master of Ceremonies, a young fellow with a booming baritone voice, clad in colorful a Hawaiian style shirt, brightly colored trousers and stylish sun glasses, strode, microphone in hand, into the center of the arena to the strains of a loud rock 'n roll theme, as the crowd applauded and shrieked their approval. Then, with a delivery that any World Wrestling Federation announcer would envy, the MC announced the team names and numbers for each robot. He did this while waving each team's flag or some other totem high above his head.

## Ethical Considerations

For readers of this study, the students who participated in the study will be anonymous to everyone but the researcher. From the beginning of the study, each participant was assigned a pseudonym. This pseudonym was the standard referent for each participant for the duration of the study. Should any subsequent presentations or publications result from the study anonymity, will be maintained. Pseudonyms were also given for all mentors who participated in the study.

I obtained the permission of the school system and the schools' principals in which the study was performed. These adults understood the nature of the research, the guiding questions that will be the focus of the research, and how it was performed. Beforehand, I explained the study to the students, as well. I told them of my interests in the spoken language that they and their sponsors used and in the other ways that they communicated their ideas to one another.

## Study Design

The study took place in two stages: data collection and interpretation. These stages were not separate or discrete activities. The overlap that existed in these two stages is a product of the Constant Comparison that was a feature of the study. Writing of conducting qualitative research, such as CDA, Michael Meyer (2001, p. 24) writes, quoting Strauss:

> Data collection is not considered to be a specific phase that must be completed before analysis begins: after the first collection exercise it is a matter of carrying out the first analyses, finding indicators for particular concepts, expanding concepts into categories and, on the basis of these results, collecting further data . . . new questions always arise which can only be dealt with if new data are collected or earlier data are re-examined. (1987, p. 56)

As the robotics team's activities were recorded and these recordings were transcribed and reduced to coded data, unforeseen aspects of the group's culture emerged. These emerging phenomena led to unanticipated questions that the study needed to address. Further, when students, team sponsors and engineers were interviewed, their responses called my attention to unanticipated themes that influenced the characterization of themes that had already been identified in the coded data. In addition, as data were collected, and coded and analysis was begun, new lines of interview questions arose for subsequent interviews.

The recursive nature of the study made it impossible to delineate the beginnings and endings of the different stages of the study. However, in the words of Gee (2005), "[W]hat we learn may well cease to change our answers to these sorts of questions in any substantive way" (p. 70), and theoretical saturation, the point in an analysis at which no "new properties and dimensions emerge from the data and the analysis has accounted for much of the possible variability" (Strauss, A. & Corbin, 1998, p. 158), was achieved.

As several authors (Gee, 2005; Meyer, 2001; Wood & Kroger, 2000) point out, no discourse analysis ever exhausts the potential interpretations that are available in a text or example of spoken language. Theoretical saturation in discourse analysis is as much a result of the theory that the analyst constructs about the situated use of language as it is about any real end to potential analysis. This means that in a discourse analysis "the notion of theoretical saturation is much more elastic" than in other qualitative research approaches (Wood & Kroger, 2000, p. 81). Wood and Kroger (2000) explain that the goal of a discourse analysis is not to be exhaustive. Rather, the goal is to find some aspects of situated language that are of interest, and to gather sufficient evidence that the claims about how that language is being used are warranted.

## Data Sources and Collection

Because this was a qualitative study, data were collected in the form of observations of language and written materials or graphic products, in the context of a high school extracurricular robotics team.

*Digital Video and Audio Recordings of Language*

Records of language were the principal source of data for this study. A small hand-held digital video recorder was used to record the spoken language of students and their mentors as they did various robotics activities. Video and audio recordings of interviews with student participants and sponsors were another source of data. The video recordings also provided a record of instances that might be the subject of field notes, such as the location of students in the work space, students' and teachers'/sponsors' gestures and facial expressions, and how students employed equipment that may be part of their activities.

The focus of this study was the use of language by students and their teacher/sponsors as they engaged in different science-learning activities with the robotics team. I was able to attend the Peachtree Regional FIRST Robotics Competition with the team and to record several extended instances of language as the team members and their engineering mentor participated in the competition.

*Other Semiotic Representations*

In addition to students' and the mentor's spoken language in the workspace and other areas of the competition venue, another source of data was documentation produced by students during the robotics competition. Documents such as these are also important to the situated language of scientists (Gilbert, G. N. & Mulkay, 1984; Halliday, M. A. K. & Martin, 1993; Roth & Lawless, 2002). These documents were collected after the competition, when the students had finished using them. I was fortunate to be able to make video recordings of the team members' discussions that resulted in the production of these artifact documents.

*Researcher's Reflective Journal*

During the course of the study, I produced notes that include my reflections on what transpired in the course of the robotics team's activities and in the process of coding the transcripts of participants' language. The journal is a record of the process through which I developed theories that led me to propose the linguistic constructs such as the Discourses that I contend were employed by the study's participants, enacted during and in response to their learning experiences.

*Interviews*

In discourse analysis, the interview is a conversational encounter through which the interviewer tries to generate interpretive contexts that permit the interviewee to produce a full account of some phenomenon. The interviewee's account, and a careful analysis of the language used to produce it, allows the researcher to construct a theory of how the interviewee makes a piece of his or her world and of his or her place in it (Wood & Kroger, 2000).

All interviews were semi-structured. For these interviews, I began with a set of prepared questions from which I departed as interviewees took novel routes in answering or required further prompting or probes. In describing the process encountered by qualitative researchers, Merriam (1998) and Wood & Kroger (2000) note that interviewers frequently develop new lines of questioning as data transcription and coding of the early interviews progresses and themes emerge from the data. Such was the case in this study.

*Student interviews.*

The nine students who were selected for and agreed to participate in interviews were interviewed once during the course of the study. The students were selected because of their level of participation in the robotics team's competition activities and the themes that I thought might emerge from their interviews, based on their participation in the competition. These themes are alluded to in various works that are cited in Chapter 2 of this study (Brown, 2006; Duschl & Osborne, 2002; Jimenez-Aleixandre et al, 2000 ; Kawasaki et al 2004; Roth, 1993; Roth & Bowen, 1995; Roychoudhury & Roth, 1996; Shepardson & Britsch, 2006). This type of purposeful sample is advocated by Lancy (1993) and Strauss (1987) because it grounds the research theory in the data that emerge from the research. Questions used in semi-structured interviews of students are found in Appendix C. These questions are loosely based on questions from the Constructivist Learning Survey (CLES) (Taylor & Fraser, 1991).

*Sponsor/engineer interviews.*

One of the faculty mentors and the principal engineering mentor were also interviewed once. The goals of these interviews were to cross check my conclusions about how language was being used by the students as they perform their roles as members of the robotics team, and to get the mentors' impressions of the emerging theories about how the students were constructing their identities through the activities and the attendant language.

The questions and prompts for these interviews focused on two areas. The first of these was the faculty mentor's impressions of science learning/teaching in the context of their science classrooms and in the context of the robotics team. I thought that it might be useful to know the teachers' impressions of their classroom students and the robotics team members' response to the different settings that were presented in their science classrooms and in the setting of the robotics team. It also might be useful to know how the faculty mentor regarded the relationships that they have with their students/robotics team members in these different settings, and the influence that these two contexts have on the methods that they chose for teaching in these different settings. Finally, in the case of the engineering mentor, I thought that it might be useful to know how the approach of the robotics team members compared with those of practicing engineers facing the sorts of challenges faced by the robotics team members. Questions and prompts that were used in interviews of faculty mentors are found in Appendix C.

## Data Analysis

As a practical matter, I had intended to use as an organizational tool an event-mapping system employed in Brown's (2004) research into the discursive identity of science students in high school biology classes. However, the pace and highly chaotic environment at FRC made this approach impractical.

I was able to make useable recordings of language at the competition in spite of the incredible din that dominated the competition and operations areas. All recordings of spoken language were transcribed verbatim in paragraph form. These transcripts were made during the week of March 16, 2008**.**

In the weeks following the production of the initial transcripts, the paragraphs of the initial transcripts were reduced to sentences, and these were broken into clauses that dealt with a unitary topic or perspective, and marked for tone units and pause. These were analyzed for the significance of stress. This was possible for the interview recordings but proved almost impossible for the recordings made in the competition venue.

Next, while listening to the original recordings, I read the initial transcripts and determined whether there were any larger natural structures, such as stanzas, in the interview answers. These were subjected to form-function and language-context analysis (Gee, 2005).

Form-function analyses examine the grammatical structure of texts with an eye to finding the sort of social work those texts are trying to accomplish through the correlations of the grammatical forms and the functions that the speaker puts them to. Language-context analyses look at how at the same instant the context influences language, while language is being influenced by context.

As Gee (2005) and other researchers (Schiffrin, Tannen, & Hamilton, 2003) point out, the requirements of a study dictate the detail of transcription and the type of analysis that is required. As Gee (2005) puts it,

> A discourse analysis is based on the details of speech (and gaze and gesture and action) or writing that are arguably deemed *relevant* in the situation *and* that are relevant to the arguments the analysis is attempting to make. A discourse analysis is not based on *all* the physical features present, not even all those that might, in some conceivable context, be meaningful, or might be meaningful in analyses with different purposes. Such judgments of relevance (what goes into a transcript and what does not) are ultimately theoretical judgments, that is, based on the analyst's theory of how language, situations, and interactions work in general and in the specific situation being analyzed. In this sense, a transcript is a theoretical entity. It does not stand outside an analysis, but, rather, is part of it . . . The validity of an analysis is not a matter of how detailed one's transcript is. It is a matter of how the transcript works together with all of the other elements of the analysis to create a "trustworthy" analysis. (p. 107)

In the case of this study, the most fruitful analyses were the ones that dealt with the larger units of language. The form-function analysis proved very fruitful in teasing out situated language from some exchanges in the W.A.R. pit area as the pit crew worked to repair a problem with the robot, and in another instance where the W.A.R. scouts were trying to determine a way of improving the analysis of their scouting data. The language-context analysis provided some useful insights into the Discourses and identities that students and their mentors enacted relative to their experiences in robotics and in science classes, or, in the case of the mentors, in robotics or their professional lives.

The transcripts from the competition and interviews were coded for themes that emerged within and among the texts. The codes changed as the study progressed, but in the end the codes that were employed were based the set of a priori codes which were Gee's Building Tasks (2005). The Building Tasks are Gee's version of the ways that language is used to construct human reality. When members of a language community speak, write or use other symbol systems, they are using what Gee (2005) refers to as "Building Tasks" to do important social work. At times a speaker or writer may consciously employ language to do a particular Building Task in a particular way, so that s/he will make a right impression with a group; but at other times language may also be employed unintentionally or unconsciously to perform a Building Task.  Gee (2005) cautions that in any particular sample of language some Building Tasks will be more important than others, while others may be entirely absent. The Building Tasks that were most evident in the study data were activities, identities, relationships, politics (in the sense of distribution of social goods) sign systems and knowledge.

These Building Tasks formed the a priori categories for codes. These served as a starting point for constructing the secondary codes that emerged from the regularities that I perceived in the data. As I reviewed the transcripts, I developed hypotheses about the ways the participants were using language to accomplish the Building Tasks during the robotics activities or while being interviewed. These theories allowed me to identify the ways in which the study's participants were using language to accomplish the Building Tasks.

For example, in the first step of coding, the passage of transcript below was coded for the Building Task Building Relationships (yellow highlighting). Next, I isolated the elements that I interpreted as the means through which the portrayal or building of relationships was accomplished. These elements (bolded and italics) gave rise to the secondary code category, Ownership and Solidarity. This is to say that I saw the use of the pronouns "we" and "our' as a means through which the interviewee claimed group ownership of the robotics team's project and showed solidarity with her teammates by casting her lot with them.

> I had never built a mechanical thing or, like, been involved in building one. And I was really surprised by how we came together. I was really surprised that *we* got all of these ideas that *we had to come together* in something that worked. Because, at first I thought, hey, *we're* in way over *our* heads here and maybe this plan isn't going to work at all, but then it really worked and I was really shocked.

These underlined and italicized segments of transcripts were extracted from their transcripts and then grouped by Building Task and secondary code.

The next step in coding was associating these segments of language with the context in which they were produced, either competition or interview. The capital letters "C" or "I" were used to draw this distinction. For passages of transcript from interviews, another level of code was added. This designated the context to which the interviewee referred during a particular passage. These were coded as robotics, classroom or outside world, and were assigned the lower case letters, "r", "cr" and "o".

The utility of this coding approach in theory building stems from the way that it permits the researcher to focus on what is important to the individual and the group to which s/he belongs. This approach provided the material from which I could construct a coherent picture of an individual within the robotics team and what constituted reality for the individual and for the other members of the robot team.

## Trustworthiness and Validity

All empirical research approaches require that the claims made on behalf of the research be justified. Lincoln and Guba (1985) propose that claims of naturalistic research are warranted and defensible when they are *credible*, *transferable*, *dependable*, and *confirmable*. However, different authors appeal to different qualities of naturalistic research when arguing for the truth claims of their research. Researchers employing a discourse analysis are no different in this regard.

A reading of a number of authors who do discourse analysis reveals some divergence in terminology from Lincoln and Guba (1985) when discussing the warrantability of research claims. However, discourse analysts do claim that a discourse analysis is warranted when the researcher provides evidence of *validity, trustworthiness, soundness* and *reliability* (Wood & Kroger, 2000, pp. 164-167). Gee (2005) writes of a *valid* discourse analysis as being a "*trustworthy*" and *credible* (p. 106) analysis. Meyer (2001) cites other criteria from discourse analysis, such as *accessibility* and *completeness*.

As with many other aspects of qualitative methodology, discourse analysis approaches the issue of validity differently. These differences spring from the philosophical and theoretical frameworks that inform these various qualitative approaches. Writing of these differences Wood and Kroger (2000) state discourse analysts use a different set of criteria, criteria that reflect an alternative metatheoretical and epistemological perspective. The concepts of reliability and validity as usually employed are intelligible at best only in treatment of matters as matters of res naturum. But it is not that straightforward for work in res artem, where there are multiple meanings and versions, none of which is "true" in the sense of correspondence to a single, material reality. Conventional approaches assume that the relation between operations and concepts is unproblematic: for discourse analysts, such relations are multiple, contentious, and socially constructed. Conventional approaches also assume that reliability can be assessed independently of context. That is, although the value of variables might vary across context, their nature does not; they are still the same variable. For example, the volume of a gas might vary from one environment to another, but the concept of volume does not change. This is not the case in the social world, in which meaning is inseparable from context (pp. 163-164). Wood and Kroger (2000) comment further that the use of the term "validity" by discourse analysts is misleading and confusing, but that they are driven by the rhetorical requirements that prevail in qualitative research to explain the relationship of the term, validity in their work to the way that the term is used in other areas of quantitative research (p. 167).

So, this having been noted, how do discourse analysts judge the validity, the trustworthiness, the credibility, the soundness, etc. of a discourse analysis? The best answer to this seems to be found in three similar approaches. Gee (2005) calls this "consistency" and Wodak (2001) finds it in "triangulation", as the term is employed by discourse analysts. Wood and Kroger (2000) also have a list of criteria for trustworthiness and soundness.

Gee (2005) writes that consistency through convergence, agreement, coverage and linguistic detail confers validity on an analysis. These elements are very similar to Lincoln's and Guba's (1985) elements of trustworthiness, credibility, confirmability, dependability, and transferability.

In Gee's approach to discourse analysis (2005), language is analyzed at several levels. Gee proposes that the analyst answer questions about how language is being used to accomplish certain social goals. He proposes that the researcher ask actual or possible producers and receivers of the language what social work they think is being done by the language. In the case of this study, this would include asking scientists, engineers, science teachers and science students about the ways that language is being used by robotics team members. He proposes that the researcher consider the verbal and non-verbal effects of the language in the present and future, that is, looking at how the past led up to words and deeds looking at similar and contrasting uses of language, and appealing to different levels of linguistic analysis and contextual factors. Gee proposes that when the results of these contrasts, comparisons and questions converge and support one another, the analysis takes on increased validity (Gee, 2005, p. 70).

Triangulation is a term that is applied widely in qualitative research. As the term is applied in discourse analysis (Meyer, 2001; Wood & Kroger, 2000), the goal of triangulation is not the same as in other qualitative research. In many qualitative research perspectives, triangulation uses multiple data sources or multiple methods to insure that the research focuses in on the correct version of some phenomenon that exists "out there," or as an attempt to reduce variability in data. Discourse analysis employs triangulation as per Denin and Lincoln (2006):

> Triangulation reflects an attempt to secure an in-depth understanding….Objective reality can never be captured. Triangulation is not a tool or a strategy of validation, but an alternative to validation. The combination of multiple methods, empirical materials, perspectives and observers in a single study is best understood as a strategy that adds rigour, breadth and depth to any investigation (p. 5).

Wood's and Kroger's (2000) criteria for trustworthiness are orderliness, documentation and audits. Orderliness refers to the clarity and transparency in the way that the research was conducted, recorded and reported. Documentation refers to the clear and complete description of how data were collected and analyzed. Audits allow readers to follow the processes through which data were collected, analyzed and interpreted. This is accomplished by providing access to transcripts and journals. In the case of this study, the researcher's reflective journal provided an account of data collection, the development of theories regarding coding and other analysis along with interpretation.

Wood's and Kroger's (2000) criteria for soundness are demonstration, orientation, and claim checking. Demonstration is showing how the analysis was developed by presenting the steps that were involved in the analysis of excerpts of language. This approach is different from simply telling the reader about the argument and pointing to the excerpts as illustrations. Orientation refers to the *participants'* orientations and concerns. This follows very closely the approach that Gee (2005) describes in his consistency criteria. Claim-checking refers to the requirement that a discourse analysis include all of the patterns that are observed in data. This generally means that an analyst will have to narrow his/her claims and acknowledge that there are alternative claims that are equally good when accounting for the full range of data.

How, then, has my study met these requirements? In this study triangulation was accomplished in several ways. After I coded transcripts of language from the competition activities and semi-structured interviews, a colleague with experience in qualitative methods that include discourse analysis reviewed portions of the coded transcripts. We compared our coding of these passages and arrived at an inter-rater agreement. This meets one of Gee's (2005) consistency criteria by providing convergence.

Additionally, I performed linguistic analyses of the transcripts at two levels. The form-function and language-context level analyses demonstrated convergence across the student team members, and in both of their mentors. Since the levels of analysis converged, this argues for the validity of the analysis. Another element of triangulation was in the review or member-checking of analyses by student team members, mentors, and a peer researcher who has a background in discourse analysis. After the analyses were completed, I discussed the results with all the study participants and received very favorable responses. The analyses were reviewed by a peer researcher who discussed the analyses with me and agreed with the results of the analysis. This meets Gee's (2005) requirement that the researcher ask actual or possible producers and receivers of the language what social work they think is being done by the language.

A further subject of triangulation were the reflective notes that I kept. The journal recounts the processes that I used in defining the units of analysis for the study, coding transcripts, and the development of hypotheses and theories about the situated use of language by the student team members and their mentors. A teacher-colleague who holds a Ph.D. in science education and who has a background in qualitative research read these reflections and discussed them with me. This debriefing by a knowledgeable colleague is an example of what Gee (2005) calls looking for "agreement among native speakers" (p.

113) on the ways language is being used to construct a social reality, and is another element of convergence in his consistency criteria.

This is a qualitative study for which context is the most important theoretical and practical consideration. The context in which this study took place is unusual. Its results and conclusions are not generalizable to all other science-learning opportunities such as the robotics team. CDA is a linguistic activity that is no less dependent on the context in which it is conducted than any other linguistic act. This is to say that a particular discourse analysis is situated in a particular time and place, and that a particular analysis may be meaningful in certain ways and not others (Gee, 2005, p. 113). I have; however, provided a "thick description" (Geertz, 1973; Schwandt, 2001) of this unusual learning context. This description was drawn from interpretations of the language that was used by the study's participants. This made it possible to draw parallels with similar situations and might allow predictions to be made about what might happen in similar situations (Gee, p. 114).

While these elements might provide a rationale for transferring the result of this study to other situations, discourse analysis in all of its forms, more than other approaches to qualitative research, relies on the reader to judge the extent to which transferability is appropriate or prudent (Gee, 2005; Wood & Kroger, 2000). "It is not the naturalist's task to provide an *index* of transferability; it *is* his or her responsibility to provide the *data base* that makes transferability judgments possible on the part of potential appliers" (Lincoln & Guba, 1985, p. 316, emphasis in the original).

## Human as Instrument

One of the chief criticisms of qualitative research in general (LeCompte & Schensul, 1999; Merriam, 1998) and CDA in particular (Gee, 2005; Wodak, 2001; Wood & Kroger, 2000) is the bias that the researcher brings to the project. "Because the primary instrument in qualitative research is human, all observations and analyses are filtered through that human being's worldview, values and perspective" (Merriam, 1998, p. 22).

I have incorporated in my study measures that were intended to guard against bias. These include the journal that I kept. It provides insight into what transpired in the course robotics activities, the processes that were used in defining the units of analysis for the study, coding transcripts, and the development of hypotheses and theories about the situated use of language by the student team members and their mentors. Another guard against bias was debriefing by a peer researcher. Debriefing provides an opportunity for a person outside of the study to comment on the processes that I employed and the judgments that I made in interpreting data. Member checking of student robotics team members and their mentors also provided another means of revealing and guarding against personal bias.

In spite of these attempts to exclude bias, a discourse analysis, as a discursive undertaking, is inextricably knit up in its context. The researcher is an important aspect of that context. From its conception, this study has been influenced by who I am. It has been and will continue to be influenced by my philosophical commitments, by the questions that interested me, by my preference for this analytic approach over others. It was influenced by the approach that I took toward the linguistic products of the study. It was influenced by the questions that I selected for use in interviews and the way that I chose to ask those questions. There is no absolute guard against these personal inclinations that constitute my bias. So in an effort to provide my readers fair warning, I make these disclosures.

I am a constructivist with regard to both epistemology and pedagogy, and inquiry is the darling of educational philosophers and educators with constructivist inclinations. Further, my beliefs about the role of education in forming and equipping citizens who are capable of functioning responsibly in a representative democracy lead me to favor an inquiry approach to education.

This is to say that I regard it as dangerous and ultimately unacceptable that an education system that is part of such a polity may privilege a student elite who experience science as inquiry, while the remainder experience science as revealed truth handed down ex cathedra. In general, I see similar approaches to education as dangerous, but currently, and more particularly in the case of science education, this danger is intensified by the deepening politicization of the scientific process and its products and the complexity of scientific and technological issues that are frequently part of public debate.

My background may be different from that of many of my study participants. Schools were institutions in which my mother and father placed a great deal of faith. They were places where I generally felt at home; they were places to which I went to succeed. These aspects of my background and experience will certainly affect my approach to this study and color the conclusions that I will draw from it.

## Summary

Science and science learning are socially situated activities in which language is of paramount importance. As with other socially situated activities, the language that is used while doing and learning science is inextricably connected to the context of those activities. Many of the goals for learning science that have been set out in important educational documents (NRC, 1996, 2000) are closely connected to the activities, language and values of practicing scientists. There is wide agreement in the science education community concerning the sorts of pedagogy that promote these goals. There is also agreement that these favored pedagogical approaches require teachers and students to adopt very different social roles in the science classroom. In Gee's (2005) terminology these different "roles" constitute different Discourses. The ways that pedagogy promotes the enactment of student and teacher Discourses is not completely understood. An understanding of these factors will fill a gap in educational theory and might help science teachers and their students attain the science learning goals set out in NRC 1996 and 2000.

A research approach using CDA was appropriate in this instance because the research focused on a description of socially situated language in a naturalistic setting, and sought to understand and describe in depth how language was used by student robotics team members and their mentors to construct personally meaningful aspects of their lives, and how power structures in the broad context of these lives impinged upon them.

The participants came from two settings: two very similar suburban high schools that are part of the same school system, HS1 and HS2. These students and their sponsors were involved in an extracurricular science-learning activity, a competitive robotics team. The selection of this setting and the participants assured the contexts needed for the study. During the research, all the participants took part in their usual activities. All of the participants were aware that they were participating in a study and understood that I was the researcher.

Data were produced for video recordings of workspace activities and interviews. Student team members' documents provided additional data. Collection of data and its analysis was continuous and recursive. To reduce personal bias, a peer de-briefer reviewed the production and coding of transcripts with me, and student participants and their mentors were consulted about inferences drawn from their linguistic production.

Finally, no discourse analysis is ever exhaustive, nor is any discourse analysis valid for all times (Gee, 2005; Wood & Kroger, 2000). This analysis has dealt only with those aspects of language that interested a particular researcher, and seemed to be useful to the researcher in answering a particular set of questions. At another time, the answers that the researcher proposed to the questions, along with the analysis that produced them, may be deemed inadequate. In this event, it is up to another researcher to show how the details of language that were omitted are important to a new analysis that takes into account other features of context that have become important in another time.

# CHAPTER 4

# RESULTS

The focus of this study was the situated language of a group of high school science students and their mentors (see Appendix A for participant profiles). The language from which the data for the study were derived was associated with two contexts. The first was an extracurricular engineering program, The FIRST Robotics Challenge in which students and their mentors design and build a robot for a national competition. The second context was semi-structured interviews that included questions pertaining to students' and mentors' experiences with the robotics program, the science classroom and their professional lives. Data for the study were drawn from two sources. One source was video recordings of students and their adult collaborators as they performed activities during the FIRST Robotics Challenge competition. The other was video recordings of interviews of students and their mentors who participated in activities leading up to and/or during the competition.

Data for the two contexts are not equivalent. Language used in the context of doing robotics is discursively distinct from language used in answering questions about robotics. However, in answering questions about what goes on in science classes and in the robotics program, students, teachers and mentors do use language to align themselves with identities, values, relationships and activities that are part of those discursive spaces.

While the data for these contexts are not equivalent, there are compelling features that arose in the analysis of data from both contexts. These features are the consistency of the comparisons and contrasts that were apparent in the way that study participants discursively constructed the worlds of robotics and their science classes. Therefore, when data derived from language collected during the robotics competition is juxtaposed with data derived from language collected during interviews, I do not contend that the data are equivalent.

The analysis of data from transcripts of language uses Gee's notion of Discourse as a lens through which to examine the study questions. The analysis argues for the role of situated language in constructing different Discourses in association with these science-learning contexts and offers mechanisms through which study participants construct the Discourses.

## Contextual Shaping of Language

Sociolinguistics, one of the theoretical underpinnings of this study, holds that language is never used haphazardly. It contends that language is always shaped to fit its context. When Gee (2005) writes of Discourses, he is writing about a very broad way t in whichlanguage is shaped and interacts with other cultural factors to fit a particular context, so that people using the language can accomplish their common goals. Discourses are about how language, in a very broad sense, gets used

> to perform and recognize activities and identities; it involves ways of coordinating and being coordinated by other people, things, technologies, symbol systems, places, times. It involves ways of being, such as, acting, interacting, feeling, emoting, valuing, gesturing, posturing, dressing, thinking, believing, knowing, speaking and listening. (Gee, 2005, p. 22)

So for the sociolinguist, the small units of meaning, words and the morphemes from which the words are built, do not provide a clear view of how meanings are made. Even when words are joined in phrases that are linked to form even larger units of the language, little is revealed about meaning because when considered in isolation, these larger units have many possible meanings. A particular meaning of a sample of English can be constructed only in light of the context of its use and the familiarity of an English user with the multifarious customs associated with other English users who occupy a particular discursive space. Gee (2005) writes of the occupants of a particular discursive space as using a common Discourse.

The analysis of data for the study uses Gee's notion of Discourse as a lens to examine the study questions. The analysis argues for the role of situated language in constructing different Discourses in association with these science-learning contexts and offers mechanisms through which study participants construct the Discourses.

The study questions were as follows:

1. How do science teachers and their students enact Discourses as they teach and learn science?
2. How does the pedagogical approach of a learning activity facilitate the Discourses that are enacted by students and teachers as they learn and teach science?

## Study Context

There is a full description of the study site and context is in Chapter 3. What follows is a brief review of factors that are pertinent to this particular discussion. The context of this study is a FIRST Robotics competition that was held in March of 2008, and the events that surround a team's attempt to prepare for and succeed in this competition. In its mission statement, FIRST says that

> Our mission is to inspire young people to be science and technology leaders, by engaging them in exciting mentor-based programs that build science, engineering and technology skills, that inspire innovation, and

> that foster well-rounded life capabilities, including self-confidence, communication, and leadership.

Language Used in Context: Scientific Language

The transcript that will follow is derived from a video recording of the pit crew of the Wild About Robotics (W.A.R.) team, composed of two students and their engineering mentor at, the FIRST Robotic Challenge competition during the March 2008 Southeastern Regional Competition. Pertinent to the immediate context of the transcript are the facts that W.A.R. has encountered difficulties during the first practice match. Two problems have emerged. First, the robot is not producing sufficient traction to run at full speed and to handle precisely. Second, the infrared control system that was used during the semi-autonomous phase of the competition has failed completely. The ambient noise in the area of the competition hall where the pit area is located is very loud. What follows is an example of language that is shaped by the immediate need to correct these technical problems. In many cases, the usage and meaning of words and phrases are a function of the context.

*Use of Scientific and Technical Talk in Context of Robotics*

Figure 1 is the transcript of exchanges that occurred in the team's preparation area, known as "the pit," at 1:30 PM 3/13/08. (Profiles of the participants are in Appendix A.)

The transcript deals with a discussion of the first problem. It has been arranged by clauses, groups of words that are arranged around and related to a subject and its predicate. The words and phrases that are of interest have been made bold and italicized. In this transcript, there are a few words or phrases that are confined to either a scientific or a technical usage. These are ***center of mass*** (6g) and ***lever arm*** (4b). All of the other

| Speaker | Utterance | Line | |
|---|---|---|---|
| SB | 1 | 1 | All right let's, let's talk about ***traction*** |
| PL | 2 | 2a | Yep, that's a problem |
| | | 2b | because I'm not getting much of anything |
| | | 2c | So, how can we get ***more traction*** out of this thing? |
| PP | 3 | 3 | We can ***concentrate the mass*** of the ***batteries over the wheels*** [Argument I] |
| PL | 4 | 4a | Don't think that'll ***change*** much |
| PL | | 4b | The change in ***lever arm is too small*** |
| SB | 5 | 5a | Let's swap these |
| | | 5b | like we did in the field test |
| | | 5c | That may be the ticket. |
| PP | 6 | 6a | If we take off the ***universals*** [Argument II] |
| | | 6b | and put on the ***gummies*** |
| | | 6c | that will ***help traction*** |
| | | 6d | because we'll go from ***passive front*** to a ***four-wheel drive*** |
| | | 6e | but it will ***change the handling*** [Argument III] |
| | | 6f | and make us even ***lighter in the front***. |
| | | 6g | We're screwed for ***center of mass***. |
| PL | 7 | 7a | Yeah, that won't help the ***hurdling*** or ***placing*** |
| | | 7b | The ***field-of- play*** is more ***like the floors at school*** |
| | | 7c | than I thought |
| | | 7d | they'd be |
| | | 7e | Yeah, maybe those ***tires are better*** |
| | | 7f | ***No problem*** with the handling |
| | | 7g | I've had time with ***that set-up*** |
| PP | 8 | 8a | All right, but why did it ***fishtail***? |
| | | 8b | Are the wheels getting the ***same torque*** |
| PL | 9 | 9a | Yeah. Well? |
| | | 9b | When we drove it like that in the other tests |
| | | 9c | it didn't fishtail |
| | | 9d | I think the new ***tires'll fix it***. |
| SB | 10 | 10a | Uh, Guys, the ***way it is geared*** |
| | | 10b | I can't see how |
| | | 10c | the wheels could get ***different torques***. |
| PL | 11 | 11a | Well, uhm, without the ***counterweight***, I think the rear gets out |
| | | 11b | of line |
| | | 11c | but I can get rid of the fishtailing by ***accelerating less*** |
| | | 11d | when I have to steer around a jam |
| | | 11e | The ***four-wheel drive'll*** help, too |
| | | | The front won't be ***passive*** |
| PP | 12 | 12a | Uh the, those wheels are bigger |
| | | 12b | so we'll have to ***reposition these wires***. |
| SB | 13 | 13a | Any other ideas? |
| | | 13b | [pause] OK, let's ***reroute*** the wiring |
| | | 13c | and swap the tires. |

*Figure 1.* Transcript from 1:30 pm on March 13, 2008. SB = Scott Bruce. PL = Patrick Limemann. PP = Patrick Pitcher.

words or phrases that are identified are used outside of scientific/technical context, and, as a result, have wide meaning potentials. Consideration of the wide meaning potential of these terms or phrases is important to this discussion because it supports my argument that the participants' language was tailored to a scientific or technical context. Even ***traction*** (1, 2c, 6c,) ***mass*** (3c), ***torque*** (8b, 10c) and ***counterweight*** (11c) have meanings outside of scientific/technical usage. In the case of ***lever arm***, as in the sentence, "The change in lever arm is too small," the subject of the sentence, *change*, is a noun that has been formed from a verb. This sort of deverbalized noun is very common in scientific or technical English (Gee, 2005; Lemke, 1990; Webster, 2004).

It may be argued that ***batteries*** (3) is an exclusively technical or scientific term; however, the word may be used in both a legal and a military context. Here the word ***batteries*** is certainly being used as a scientific/technical term, but not in its most common usage, an electric power supply, such as, "The robot is powered by batteries." However, as part of the phrases "…***concentrate the mass*** of the ***batteries over the wheels***" it is clear that the speaker means that the batteries should be used to change the distribution of mass for the robot by positioning the batteries over the wheels. In this context "batteries" is a suggested solution to the traction problem that the team has experienced in the first practice match, not as an electric power supply.

Here ***tires*** (7e), as is most common, are a means of supporting and providing traction for a vehicle or some other mobile device, but this is not the only meaning that the word can have. In the context of two young people looking at a car, and uttering "Yo! Dude, those are bitchin' tires!" tires are not a means of support or gaining traction, in its usual sense; tires here are a means of achieving some sort of aesthetic or of conveying status as the owner of a car so tired. In the transcript, the meaning of “tires” is even more specific in referring to ***gummies*** (6b), tires made of a tacky gum rubber that may offer better traction, but at the same time make the already-too-light front end of the robot even lighter.

***Universals*** here are not immutable truths. ***Universals*** is a shortening of universal wheels, ball-in-socket type wheels that are very heavy and offer greater maneuverability than fixed front wheels. Along with ***gummies***, ***universals*** are part of the jargon used by members of the robotics team.

In all of these cases, the language that is used in the pit area is shaped by the context of the team’s technical difficulties and their need for a timely solution. Solving technical problems calls for technical talk that everyone involved can understand and apply in aid of problem analysis and a solution.

*Dialogic Argument*

Another feature of the transcript of language recorded in the pit area after the first practice round are the exchanges between Patrick Limemann (PL) and Patrick Pitcher (PP). There are several important linguistic features that are part of the give and take. Although there are three speakers involved, in this section, I will consider only the exchanges between Patrick Limemann (PL) and Patrick Pitcher (PP), student members of the team. In a later section, I will consider in greater detail the role of Scott Bruce, the team’s engineering mentor, in these exchanges.

At the beginning of the transcript, Scott Bruce establishes that the robot has experienced a traction problem during the first practice round. So, it is not surprising that PL’s and PP’s language focuses on this issue. In fact, much of PL’s first utterance (2a-

2b),“Yep, that’s a problem because I’m not getting much of anything.” was, in essence, an endorsement of SB’s bid (1) to make traction the topic of the discussion. PL finishes this utterance by posing the essential question, “How can we get more traction out of this thing?”

PP offers an answer to this question (3), posing an argument that I will call Argument I (See Figure 1). In Argument I, he makes the claim that the traction could be addressed by repositioning the batteries closer to the rear wheels. PL rebuts PP’s argument by claiming that he doesn’t think PP’s solution will help much (4a) and offers a backing reason (4b) for his judgment. PP’s and PL’s pattern of an argument is based on observation followed by a rebuttal, or an agreement that is empirically testable These are scattered throughout the transcript. The rebuttals or agreements do not always immediately follow the argument that they address.

In Utterance (6) PP makes three arguments. Argument II is found in clauses (6a-6c), and Argument III is in (6e). Argument II begins with PP’s claim, “If we take off the universals and put on the gummies, that will help traction . . . ” He backs the claim in (6d) “… because we’ll go from passive front to a four-wheel drive.” There are no rebuttals to Argument II. Instead, in clauses (7b-7d) PL agrees with the claim of Argument II. His agreement is, “Yeah, maybe those tires are better.” and he offers backing for his agreement, observing that, “The field-of-play is more like the floors at school than I thought they’d be.” Here he is referring to testing the robot on a surface similar to the field-of-play, with the same wheels and drive train arrangement that have been suggested to improve the robot’s performance.

Argument III (6e) is, "… it will change the handling…." This refers to the result of changing the wheels/tires and the drive train. PL's rebuttal (7f) is, "No problem with the handling." This is backed by (7g), "I've had time with this set-up." The rebuttal refers to PL's success in driving the robot with the stickier tires and the different drive train during practice at the school.

(6g) "We're screwed for center of mass" is the last argument in utterance (6). PL's response (7a), "Yeah, this won't help the hurdling or placing," is in agreement with PP's claim. Both of these statements refer to the problem that the team encountered at the weigh-in. The robot was 1.7 lbs above the 120 lbs allowed by FIRST, and this weight did not include the 20 lbs of counterweight that the team hoped to use to stabilize the robot. The boys understand that changing the front wheels from the heavier and more steerable universal wheels to the lighter fixed gummies will exacerbate the problems caused by the light front end. In (7a) PL is referring to "… hurdling and placing …," which are scoring maneuvers in the competition that require raising the rather heavy rack-and-arms apparatus that is located at the rear of the robot. So PL's comment is effectively that with a lighter front end, raising the robot's rack-and-arms will make the robot even more prone to tipping over than it would be with the heavier universal wheels in place.

In utterance (8) PP asks two questions. Referring to the robot, he asks (8a), "Why did it fishtail?" and (8b),"Are the wheels getting the same torque?" I view these questions as an argument composed of a claim with backing. The backings for these claims are not stated, but PP raises no objection to this because the backing for the claim is present in the group's understanding that different torques applied to each wheel will produce fishtailing. It is interesting that PP used interrogatives for this argument. I will address this in another part of the analysis. The argument might be made in a declarative form, as, “I think that the robot fishtailed because the wheels are not getting the same torque.”

PL’s rebuttal of PP’s argument is divided between utterance (9) and (11). First, PL follows (8) with a dismissal (9a), “Yeah. Well?” PL’s makes two rebuttals of PP’s claim (9c and 11d &11e). Both amount to saying “the problem’s not torque; it’s the wheels and drive train.” As PL puts it (9c), “I think the tires’ll fix it ,” and (11d & 11e) “the four-wheel drive’ll help, too. The front won’t be passive.” These claims receive backing in several places. First, (9b-9c): “When we drove it like this in the other tests it didn’t fishtail.” “When we drove it like this…” refers to tests of the robot when the wheels and drive train were in the same arrangement as that proposed for the fix. PL backs his claim further in (11a-11c) by listing other things that might have caused the fishtailing. These alternative causes for fishtailing are unrelated to issues of torque. Utterance (10) is SB’s rebuttal of PP’s argument. This was discussed in an earlier part of this chapter.

The pattern that emerges from PP’s and PL’s contribution to the language depicted in the transcript is Argument followed by Rebuttal or Agreement. These are built on empirically based claims and backings that frequently come out of the robotics team’s experiences and the team’s acceptance of common theories about how the robot works that have been developed around those experiences.

This structure of argumentation used by PL and PP in their pit discussions and their means of validating knowledge has been described by a number of authors. Toulmin (1958) reported that, like other communities of practice, the scientific community employs mutually agreed standards of validity to its arguments. For scientists, this means that argument must be empirically based and theory-dependent. Duschl and Osborne (2002) describe the approach as "a special case when dialog addresses the coordination of evidence and theory to advance an explanation, a model, a prediction or an evaluation"(p. 55). In addition to their arguments' structure, within these scientific arguments there are examples of lexicogrammatical features associated with the scientific register. In the case of PP's and PL's arguments these are deverbalized nouns (Webster, 2004) in the form of participles. In each case, the clauses containing the deverbalized nouns can be restated using the verbs from which the nouns are derived without changing the meaning of the clause. For example, in (11b), "… I can get rid of the fishtailing by accelerating less…" contains two deverbalized nouns, *fishtailing* and *accelerating*. This clause can be restated as two clauses: [It won't fishtail] [if I accelerate less]. There is no change in meaning, but this less lexically dense construction is not typical of scientific register.

As mentioned earlier, many of the backing elements of PP's and PL's arguments come out of the robotics team's experiences and the team's acceptance of common theories developed around those experiences. This way of forming theories and validating knowledge is very common among communities of practice (Gee, 2005) such as groups of scientists (Gilbert & Mulkay, 1984) working together on projects.

It is clear that PP's and PL's use of dialogic argument, features of scientific register, ways of forming theories and validating knowledge have much in common with the linguistic practices, values and beliefs of practicing scientists, but how do these discursive resources get used in the particular social context of the pit crew?

Here, I make the argument that PL's and PP's language is situated in and fitted to a particular context. Another analyst might argue that this is not the case, and that what is recorded in the transcript is a common feature of robotics team members' ordinary day-to-day speech. As counterpoint to this sort of claim, I present a sample of argument that shows that members of the robotics team do not always employ this pattern of argumentation (see Figure 2).

| | |
|---|---|
| SJ | I'd rather die than be seen on a hog. Hog's a good name too! Look at the leather-wearin'-greased-up-stud-wearin'-prison-inked skanks that you see on those bikes. |
| PL | You're not man enough to ride a hog. A rice burner is about right for a skinny pussy like you. And if you think that the chicks that ride Harleys are greasy skanks, you're not looking. Boys on pocket rockets ride solo because the chicks know they're gay. |
| SJ | If you ever see a hot chick on a Harley, it's when the guy up front is a poser doctor or lawyer out playing bad boy on the weekend. |

*Figure 2.* Transcript from evening of March 14, 2008. SJ = Shaggy Jones. PL = Patrick Limemann.

In this sample of language, a different pattern is used. The exchange took place at a meal in an entertainment complex/restaurant on the night of 3/14/08. Patrick Limemann and Shaggy Jones are discussing the merits of Harley Davidson motorcycles, a domestic brand of motorcycles, and Japanese motorcycles. The transcription does not reproduce the interruptions that were part of this exchange.

This is an example of two young men talking "smack." They are both making arguments, but the validity on which their claims and backings rest is not empirically based. Instead, their validity rests on acceptance of social theories about status and manhood that are parts of clashing Discourses within a segment of society. This stands in contrast to the dialogic style of argumentation that PL and PP engaged in during the exchanges in the pit area.

*Language in Context: Student Identity*

One of the themes that appeared in the analysis of the transcripts of student team members' language was identity. This theme was developed through a number of discursive features that were apparent in the language that was taken from video recordings made during the FIRST Robotics competition and during semi-structured interviews conducted with student team members. This theme and those discursive features will be treated in this section.

Gee (2005) refers to Discourses as coordinating people in relation to place and time. By this, he and other authors mean that when people work together toward a common goal, over time, their activities and the language that accompanies them become dependent on group history and an identity that the group develops as a result of shared experiences (Gee, 2005; Gilbert & Mulkay, 1984). Such is the case for W.A.R.

Therefore, the context of the language in the preceding transcript is not fixed in time. An understanding of the discussion that is recorded in the transcript depends on a shared knowledge that is connected to previous events and the team's experience of them.

*Language Establishes Group Identity Through Shared Experiences*

The team learned about the robot through earlier experiences and the experiences form the basis for the team's beliefs about how the robot works, and in this case how traction might be improved. Several of the marked phrases, such as, ***help traction, passive front to a four-wheel drive, change the handling, lighter in the front, like the***

***floors at school, tires are better, that set-up, tires'll fix it, and reposition these wires*** relate to shared previous experiences and the knowledge that the group gained from them. For example, Scott Bruce's instructions to "***reposition these wires***" is not accompanied by any instructions for how they should be repositioned. This might have been an oversight, but since a member of the pit crew did the work without further instructions, it must mean that Scott correctly surmised that, on the basis of previous experience, one of the crew knew how the job should be done. Patrick Limemann, the lead driver, commented that he "had time with ***that set-up***" so the team apparently had experience with the alternate arrangement of the front wheels and the drive train. It is likely that, during pre-competition testing, the crewmembers had already seen the arrangement, and understood that the change of front wheels required a change in the drive train that would interfere with the wires in their current position. Similarly when SB gives instructions for modifications and follows them with "… like we did in the field test.," these are instructions that rely on the rest of the crew, PL, PP and others that joined them for the actual wrench work, to remember what was done at the field test.

These earlier experiences and the knowledge that are their results are essential to the group. They are valuable to and valued by the team because they are means by which the team can achieve its goals. This knowledge and these experiences are also part of a team identity. This knowledge identifies the team as "people like us who know and understand this sort of stuff about this particular robot."

*Dialogic Argument and Thinking Together*

Dialogic argument is distinct from rhetorical argument. In rhetorical argument, the goal is to destroy an opponent's credibility through rhetorical technique, rather than through the empirically based strength of an argument. Except that the opponent might make a rhetorical error, and provide the arguer with opportunity to land a blow, the opponent is of no consequence to the arguer.

In dialogic argument, the other side of the argument is not so much an opponent as he or she is a partner in a debate. Several authors (Dawes, 2004; Mercer et al., 2004; Salyer, 2000) identify dialogic argument as a technique for thinking together.

In this section, I will show how dialogic argument functions as a discursive feature. I will show how dialogic argument is used to establish ownership of the robotic team's project and solidarity among its members, and how it is used to establish ownership of the project through group-determined standards for the validity of knowledge. The section will draw on transcripts of language gathered during the FIRST Robotics competition and during semi-structured interviews of student team members.

In an earlier section of this chapter, I argued that dialogic argument was a feature of Patrick Pitcher's and Patrick Limemann's exchanges in the pit after the first practice round. I argued that PP's and PL's exchanges use dialogic argument, scientific register, ways of forming theories and validating knowledge that have much in common with the linguistic practices, values and beliefs of practicing scientists. Here, I want to consider how these discursive resources get used in the particular social context of the pit crew.

It is tempting to say that the arguments of the pit crew are the key to diagnosing and fixing the robots' traction problem. I do not think that this is the case. I contend that the purpose of their argumentation is revealed through an analysis that includes all of the speakers in the pit area. In this analysis, I argue that SB actually controls the exchanges that are responsible for both the diagnosis of the traction problem and its correction.

Returning to the transcript, we see that in the first utterance (1) SB invites the group to talk about traction as the problem. I interpret this not so much as an invitation to discuss, but as announcement of a problem that needs to be fixed. In light of the time limitations that the team is under, it is not surprising that SB in his role as mentor addressed the problem and the group in this way. Examination of the transcript shows that PL (2a) understands SB's invitation to talk traction as a declaration of the problem, too. It is also clear that he agrees with him. In clause (2c) PL poses the question, "… how can we get more traction out of this thing?" In Utterance (3) PP tells what he would do to fix the problem. In Utterance (4), PL dismisses PP's idea, and in Utterance (5) SB essentially tells the boys what to do to fix the problem.

In terms of the number of utterances in the transcript, SB's solution to the problem (5a) comes a bit before the halfway point, and in terms of the total number of clauses, his solution comes well before the halfway point of the transcript. After choosing the solution, SB has only two short utterances of the remaining eight. So, if the important issues for the pit crew were resolved so early in these exchanges, what was the purpose of the rest of the language? Why do the boys continue with their discussions?; or by contrast, why didn't SB simply get the crew back to the pit and say, "Change the wheels before the next practice round"; or by contrast, why didn't SB open comments by asking, "What do you think is the biggest problem with the robot's performance?" With regard to improving the robot's performance for the next practice round, the result would have likely been the same.

The boys' arguments make up most of the remaining transcript. However, if at this point in the transcript, the improvements to the robot have already been decided, their arguments are not part of a decision-making process. If this was not their arguments' purpose, they must have served some other purpose or, simply, they were purposeless idle chatter. I contend that the former is the case. I contend that they are using their arguments to think together about the consequences of the modifications that SB has identified. Their thinking out loud is not the same as an inner monologue; it is dialogic, multivoiced. When PP says (6a-6g),

> If we take off the universals and put on the gummies, that will help traction because we'll go from passive front to a four-wheel drive. But it will change the handling and make us even lighter in the front. We're screwed for center of mass,

he is responding to SB's (5a). PL (7a-7g) continues this pattern in response to PP:

> Yeah, that won't help the hurdling or placing. The field-of- play is more like the floors at school than I thought they'd be. Yeah, maybe those tires are better. No problem with the handling; I've had time with that set-up.

In both of these passages it is possible to see the beginnings of the elements of tactics and strategy emerging for the next practice round. PP and PL are beginning to form ideas about what advantages and limitations will result from modifications to the robot.

The role of scientific argument as a thinking tool is well documented in research (Dawes, 2004; Mercer, Dawes, Wegerif, & Sams, 2004). This fits well into Toulmin's thoughts on scientific argument as it relates to "the *coordination of evidence and theory to advance* an explanation, a model, *a prediction or an evaluation*" (Duschl & Osborne, 2002). Toulmin's work (1958) on types of arguments identifies these features as the defining characteristics of scientific argumentation.

*Ownership and Solidarity through Thinking Together.*

PP's and PL's arguments have little to do with the diagnosis and the fix for the robot's problem, but still, analysis of their language indicates their ownership of the project. They demonstrate this ownership in spite of the fact that Scott Bruce essentially prescribed the pit crew's activities.

Analysis of the pit crew's language shows that they are more than SB's laborers. If they were not, SB might have returned the group to the pit and simply said, "Change the wheels before the next practice round." In contrast, if this were entirely the students' project, SB's opening comment after the first round might have been, "What do you think is the biggest problem with the robot's performance and what do you want to do about it?" One might Consider this language from another point of view: if it were entirely the students' project, why were the adults there doing anything beyond supervising the general behavior of the students?

There are four instances, (1), (5a), (10a) and (13b), in the transcript where SB's utterances contain attempts to promote solidarity. In three of these he uses "Let's", the abbreviation of "Let us." The use of "us" includes everyone working in the pit with every aspect of fixing the robot.

In the case of the students, they use first person singular and plural personal pronouns in places where this might be avoided, or an indefinite pronoun might be used instead. For example, PL's question in (2c) is "How can we get more traction out of this thing?" This might just as easily and without loss of meaning have been, "Is there any way to get more traction out of this thing?" PP's (6a-6e) "If we take off the universals and put on the gummies, that will help traction because we'll go from passive front to a four-wheel drive…" might have been, "If the universals are replaced with the gummies, that will help traction because the front end won't be passive and the robot will have four-wheel drive." These and other examples from the transcript illustrate how the students use language in thinking together, which I contend is only possible because of the solidarity that already exists in the team and contributes to reflexively building increased solidarity and ownership in the group's project.

*Ownership and solidarity through group determined standards.*

There is another incident from the competition that illustrates the student ownership of the robotics program. It happened on 3/13/2008 from 12:45-12:55 PM (see Figure 3). The incident occurred as members of the robotics team who had volunteered to serve as scouts met after observing early practice rounds. Each scout was assigned to observe the performance of several robots. In addition, they were to visit the pit areas of the teams responsible for the robots, interview the team members and make a close-up inspection of the robots' construction so as to get a sense of its durability and capabilities that

| Speaker | Utterance |
|---|---|
| NS-1 | 1102, the, green one, has really good way of knocking the balls off the, uh, rack [SA: the same thing it uses to pick'em up?]. Yeah but it's not so good for that. Uh, good speed too, but like I said not so good for hurdling. |
| HF-1 | Wait! Dude! I saw it on the test field and it hurdled great. |
| NS-2 | It stunk in the practice round. Maybe there's, uh, like, a problem? |
| SJ-1 | OK. After go back and talk to the crew and see if maybe they, uh, didn't try hurdling in that round or what, OK? |
| NS-3 | Yeah, movin' on. Alright. Uh, the driver's not bad, but the 'bot was broken at the end of the round. There was a lot of bangin'. I asked about the repairs and the crew chief said it was no problem. Good herder and a definite rabbit. I'd say it's pretty strong overall. |
| SJ-2 | Does it do hybrid? |
| NS-4 | Uh, Yeah it went flyin' down and slammed the wall. So, it got two lines but it probably didn't help the mechanics much. |

*Figure 3.* Transcription from 12:45-12:55 pm on March 13, 2008. NS = Nolan Strange. SA = Stretch Armstrong. HF = Hans Fowler. SJ = Shaggy Jones.

might not be obvious from observing them at a distance during the practice rounds. Shaggy Jones ran the meeting. There were no adults involved in this meeting.

For these initial observations, the group used the basic rubric provided by FIRST. During this meeting, the students determined that an important type of data was missing from the scouting sheet. They noted that some of the teams scored a lot of points, but that some of these teams were also penalized quite a few points for infractions. In response to this observation, a discussion ensued regarding what to do about this shortcoming in the scouting report ensued. The students decided that they would calculate a ratio of points scored to points penalized. It was agreed that one of the team's members would collect the pertinent data, do the calculations and keep the records. The participants in the discussion were Shaggy Jones (SJ), Stretch Armstrong (SA) and Nolan Strange (NS), Hope Wedgwood (HW), Faith Wedgwood (FW), Hans Fowler (HF), and Philemene Aaron (PA).

Most of the transcript is made up of scouts' reports of the performance of robots in practice rounds. In this exchange, NS has the floor and is reporting. He is interrupted twice, once by SA and later by HF. HF disagrees with elements of NS's report. Following the interruptions, SJ calls the scouts back to order and suggests a way to resolve NS and HF's disagreement. NS resumes his report, fields a question and concludes.

This stretch of transcript portrays an activity that remained completely student-centered and controlled for the entire competition. At one point because of the apparent lack of involvement by sponsors and mentors, I began to wonder whether scouting might not be an activity designed to keep the scouts occupied and out of trouble during the competition! However, when the team qualified for the finals and became involved in choosing strong partners for a competition alliance, the data that the scouts collected became key elements in the discussions of which teams would be chosen for the alliance.

The elements of dialogic argument over the shortcomings of the data collection form reached their peak in a segment of the transcript (see Figure 4) that deals with what several of the scouts felt was a shortcoming in the data that were being collected. SA and HF were discussing the performance of two robots. They observed the ways that the robots scored points, but they also observed that the teams committed a lot of fouls that would cost them points when competition began. Other scouts pointed out that they had observed the same things. SJ decided that this was important and that the observation should be reflected in the scouting reports. He opened the floor for suggestions for how this aspect of performance should be reflected. A discussion ensues (see Figure 4).

In this passage, there are all of the elements of dialogic argument that were featured in the first passage from this episode. But what is most important about this portion of transcript is that it marks a point where the students step away from what I imagine were the practices and values of most of the teams that were in the competition, the standards provided for in the FIRST scouting report. Examples of the FIRST Scouting Reports are in Appendix D. The scouts decide, on the basis of sound dialogic argument, that the stock scouting sheets provided by FIRST did not provide the information that they felt was needed to do their jobs. Their decision is prompted by the perception of a need. Their solution reflects the scouts' ownership of their jobs and the attendant responsibilities. They chose a solution based on a consensus that is forged from arguments that are made before the group. This approach is possible because of the faith that the group has in its ability to think together, and in its leader. The success of this

| | |
|---|---|
| SA-1 | Yeah, right dude! 1957's hybrid's got a flipper made from plastic from a pool toy that knocks a ball down and they get two lines too. So, they get 20 points there. It's got good speed and maneuvers well. Good driver. It knocks down balls really strong. Good speed too. It doesn't hurdle well. I didn't see it, but it might place balls too. It scored points but the refs'll penalize it a lot for knocking other robots in their zone. |
| HF-2 | It's (robot #?) a lot like ours but it doesn't have good control. The lifting rack is two stage not three. The arms can scoop or grab but the ball slips out most of the time. It uses a bungee chord around the arms to capture the ball, slow and it won't hurdle. They might be able to place balls but I doubt it. I think the speed is about the same as ours but the driver's not so good. They'll lose a bunch of points in penalties too. |
| PA-1 | I saw it in mine too. |
| SJ-3 | Anybody else see that? |
| FW-1 | Lost points for penalties? |
| SJ-4 | Yeah. |
| [General, unintelligible cacophony!] | |
| SJ-5 | Ok. Um, if that's a problem, we need to scout it. We need to show that in our reports. How do we do it? |
| HF | We could calculate a ratio of points scored to points penalized, or something. |
| SA-2 | Ooow? How about net points? It's [PA: Um, No!] easier. |
| PA-2 | Um, uh, Net points might tell us what we need. What if we can't scout all the matches? Um, If we calculate net points, then, like, for the te-teams that we scout a lot it might look like, um, they're better than they really are and for the ones that we don't they might look like they're not so good. Well, um, the ratio won't change as long as they don't change something about what they're doing like a better driver or something. |
| [General, unintelligible cacophony! Apparently SJ understands that there is a call for justifying the usefulness of this metric] | |
| SJ-6 | Why? Um, well [HF: They assign the alliances. Like, we don't get to choose who we play with and against] well, we can talk to the other teams, um, and ask the driver to take it easy and not bump in the zone and stuff. And we do choose if we get to the finals, so we can definitely use it.<br>Alright, hold it! Shut up! Um, What do you want to do? We don't have much time before the next rounds. We've gotta move. Let me see the hands of everyone that wants a measure of points scored and points penalized. OK. So, good. Which kind of measure? Raise your hand if you want the ratio. OK, it's unanimous. I'll tell Zippy to get the numbers and to put it on his spreadsheet. Um, OK, let's go back and scout the next two rounds and meet at 3:00. Stop! Hold it! Let me have all the scouting sheets. |

*Figure 4.* Transcription from 12:45-12:55 pm on March 13, 2008, continued.

approach to problem-solving is a measure of the group's solidarity. An example of the Score Recap sheet that resulted from this interaction is in Appendix E.

This sort of discursive act is characteristic of communities of scientists and engineers. Just as communities of scientists and engineers do, the community of scouts used their language to set standards for what will be privileged as legitimate and useful knowledge within their community.

*The language of ownership and solidarity: contrasts in context.* The linguistic features that demonstrate the student team members' ownership of the robotics program and solidarity with one another in pursuing their goals is not confined to transcripts of language recorded during the FIRST Robotics competition. They are noteworthy features of language that is found in the transcripts of each and every one of the student participants' interviews. In addition, the interviews add constructions employing "us" and "our" to those previously mentioned. Instances of these features are not rare, but are prominent features found throughout the student participants' interview transcripts. Equally interesting is the complete absence of these expressions in interview references that student participants make to activities in the science classroom. As with the transcripts of the language of the pit crew, in the transcripts of interviews, these constructions are used in place of alternatives that would not change their meanings, but would eliminate or add expressions of ownership and solidarity.

For example, comparing the sorts of things that he did in robotics with the sorts of things he did in science class, Shaggy Jones (SJ) said,

> OK then, the math and science is the same but the hands-on doesn't quite reach the same level then, the robotics ***we're*** working with ***we're*** cutting metal, molding, ***we're*** putting together a six-foot-tall 120-pound that could, I mean, if ***we*** don't follow safety procedures it's more drastic than

> if ***you*** don't follow them in the teacher's classroom. In the classroom ***you*** use the 1.5-volt batteries and it's just not as real. In robotics ***we*** work with these huge motorcycle batteries rather than the dinky household batteries. And the wiring we're working with, wiring that has to support, you know, many more volts, 10 times as much volts or current as any wiring you have here in class. You…the mechanics if it's the arm it comes around and hits you it could break your arm. When you're working with little teeny fan motors in physics. (C[1-3])

Contrast the way that SJ refers to activities in robotics with the way that he refers to things that he did in science class. In each instance the "we" or "we're" could be swapped with a less personal construction without any change in meaning. For example, "… the hands on doesn't quite reach the same level then, the robotics *we're* working with *we're* cutting metal, molding, *we're* putting together a six-foot-tall 120-pound …" could just as easily and meaningfully be "the hands on doesn't quite reach the same level then, the robotics *you're* working with *you're* cutting metal, molding, *you're* putting together a six-foot-tall 120-pound …" . From the same passage and referring to classroom science activities, Shaggy says, "…it's more drastic than if *you* don't follow them in the teacher's classroom. In the classroom *you* use the 1.5-volt batteries and it's just not as real …" (III [1n-2c]). This could be changed to "… it's more drastic than if *we* don't follow them in the teacher's classroom. In the classroom *we* use the 1.5-volt batteries and it's just not as real. ..." without any denotative alteration of meaning. These passages that exhibit these features are not unusual. The pattern is found throughout the transcript of SJ's interview.

SJ had already mentioned that robotics was different from his physics class labs, so as a follow-up to his answer, I asked a question about the things that he felt were responsible for these differences. Shaggy responded that limited time was a difference, saying

> In robotics it takes *us* six weeks to do one project because it is so huge. *We* haveta' plan everything out, safety is a huge deal, so, I mean, *we* have ta

> do everything by the books and *you* don't have time to do these things in physics. *You* can't just take six weeks out of the curriculum and do a project 'cuz *you* won't get what *you* need done and so *you* have to do the couple-of-day labs, one two three maybe a week, at most, but never a six-weeks project and that is why robotics isn't part of the curriculum, at the moment. (D [1-3])

Again there is the contrast between the pronouns that are used by SJ as he describes what was done in robotics and in physics class. This contrast is particularly interesting when the fact that Elizabeth Bruce, one of the robotics sponsors, was SJ's Advanced Placement physics teacher at the time of the interview. I will talk more about this contrast later.

Another example of this pattern is found in the transcript of Pavlova Kinsky (PK). PK is a different case because she is one of the comparatively few females on the team, and she is the only interviewee who did not attend competition. To a question about experiences from robotics that she thought she might carry into later life, PK mentioned that she got comfortable in a field that she had never had experience in, so as a follow-up I asked her what field that was. Her response was

> I had never built a mechanical thing or, like, been involved in building one. And I was really surprised by how ***we came together***. I was really surprised that ***we*** got all of these ideas that ***we had to come together*** in something that worked. Because, at first I thought, hey, ***we're*** in way over ***our*** heads here and maybe this plan isn't going to work at all, but then it really worked and I was really shocked. (C[1-4])

In this response, PK makes no contrast with activities that she has done in science class. However, in her response to a question about these activities, she does talk about differences. Here there are two cases where "we" is employed in conjunction with the verb "to come together," which makes their use even more indicative of solidarity and ownership.

*Female Identity*

Thus far this section has been concerned with the discursive devices that student team members employed to establish their identities as owners of the robotics team's project, united in pursuit of its goals. While the data and its analysis permit the presentation of many examples of this language, there are also passages of language in the transcripts of the female members' interviews that show that their status in this project was not the same as their male team members.

*Female members' status.* While observing the robotics team members carry out their activities, one finds it difficult not to remark on the relative numbers of girls and boys. The ratio of boys to girls participating in the FIRST competition in March of 2008 was 2:1. If this examination is extended to the group that participated in the design and build portion of the team's season, the ratio of boys to girls rises to about 3:1.

As a result of team makeup, and in patterns of participation within the team, I asked the female members of the robotics team about their experiences on the team. I began my questioning by asking a general question designed to determine if the female members of the team were aware of their relative representation on the team. Following the response to this question, I generally asked, "Why do you think this is so?" Following this I asked questions that led to elaboration on the theme of being a female member of the team.

*Girls' world/boys' world.*

All of the girls who were interviewed recognized that they were a minority on the team. They offered a variety of reasons for this situation. Philemene Aaron put the difference down to, "I guess because boys are just more involved in things like robotics.

Other than that, I really don't know." Hope Wedgwood said, "Well, the girls ended up being more of the um, the, like, planning our uniforms, like what the robot would look like, the art and promotion and web stuff. It's like more of a girlie thing" (XIII[1-2]): Pavlova Kinsky remarked that when it came to building the robot, "we let the guys do it all because they seem more sure of the building process" (XI[1f-1g]).

All of the girls interviewed, except for Pavlova Kinsky, had minor involvement in the building of the robot, but by competition time none of the female members of the team was involved in operating the robot or the pit crew. Two did function as "robo-coaches," activators and controllers of the robot during the semi-autonomous phase of the matches. By the time of the competition the girls were principally involved in scouting and various areas of team promotion.

About her participation in the build Faith Wedgwood said,

> I put wheels together and worked on the chassis and the forklift arms. I and Hope did more of that than the other girls. Some of the things that I built didn't make it on the robot but I helped to build. (H[2-4])

Later in her interview, to the question, "So why do you think that members ended up doing what they did? What motivated them?" she commented,

> Well, um, I think that we just picked. There were a lot of invitations for the girls to come and build. That's how we got to do it. There was a real push for us to come and participate, maybe even because we were girls. Um, *hrmp,* I hope I do get to do more next year, but it may have been because we were just, like, standing around just kinda watching and they'd be like, hey, guys, come do something. Um, but, I don't know, it was pretty equal. I think that if it was just somebody standing around, I don't know if our gender really made any difference. (R[1-6])

To the question, "Why do you think there are fewer girls than boys on the team?" Pavlova Kinsky responded,

> A lot of us feel like, even though we feel like we should be equal members and we should all get to do the same things some of us are afraid to not, to

> try and building stuff, and we let the guys do it all because they seem more sure of the building process. The girls were also interested, but they- a couple of us were really interested in the actual like operation once everything got built, like the maneuvering, like how it was going to work in the competition, ‘cause Velvet was really interested in the wiring of the remote, and she made sure that everything was going to run smoothly out there, and I guess that we got more into the competitive aspect than in the actual building of the mechanical process. (K[1-2])

I followed Pavlova’s response by asking what she meant by the “competitive aspect.” To this question she responded,

> My group had to come up with a list of ways that we could make our team better, and most of these things had to do with stuff we could do in competition. How we could reduce the number of repairs that we would need to make and how we could reduce the amount of money needed to make them. And we all got really into how, once we got there, how we were going to show good sportsmanship and how we were going to show our respect for other teams, but at the same time understand that we needed to focus on us and what was going on with our robot. So we spent a lot of time with that. All of what we did was important because you can build a robot, but if we don’t transport it and all the other stuff to the competition, we can’t succeed. We needed to be able to get into and out of the arena as quickly as possible. Everyone needs to be kept informed of what we were going to do and when we were going to do it. Our success required all of the team. (L[1-8])

The girls from the team gave answers to interview questions that included elements that identified them as outsiders. Several of the female team members gave answers to interview questions that divided the team’s activities into those suited to or liked by girls and those suited to or liked by boys. Hope Wedgwood’s (HW) choice of the term “girlie” to describe the tasks done by female members of the team is significant. The most significant aspect of HW’s choice is the absence of an equivalent term to denote tasks suited to or preferred by boys. In this case, the term seems to be employed as an adjective that describes activities that are a sort of “girl thing.” However, the word may also mean overly girlish. Further, the term’s similarity and etymological ties to the dismissive and offensive noun, “girlie”, should not be ignored in this case. It might be argued that HW was not aware of the other uses and connotations associated with girlie and that her choice of the word is unconnected to these. However, I am certain that she, like native English speakers of her age and social background, was aware of the use of "–ie" to form the diminutive of many English nouns and is aware of the dismissive connotation that may be associated with these.

*Girls outside looking in.* While Faith Wedgwood said that she felt that the girls on the team chose their roles, and that in the end she's not sure that their gender made a difference, she also spoke of the girls' being *invited* to participate in the build. She said, "There were a lot of invitations for the girls to come and build. That's how we got to do it. There was a real push for us to come and participate, maybe even because we were girls" (XVIII[2-4]). Outsiders are invited; members, those that belong, do not need invitations. Further, the sentence, "That's how we got to do it," implies that the girls who participated in the build were *allowed* to participate rather than entitled to do so.

Pavlova's comments also indicate her status as an outsider. She remarks,

> A lot of us feel like, even though we feel like we should be equal members and we should all get to do the same things, some of us are afraid to not, to try and building stuff, and we let the guys do it all because they seem more sure of the building process. (K[1])

The subjunctive mood of Pavlova's statement is about what is not yet true for her and the other girls on the team. The assertion that she and the others should be equal members and that they should all get to do the same things is a comment on their lack of equal status with the boys. However, her answer to my question about being involved with "the competitive aspects" of the competition has a tone of personal satisfaction and is a statement of solidarity with the team.

It is clear that girls do feel that their experience and status within the team is different from those of the boys on the team. According to one of the girls, their participation falls short of what it should be, and they are not satisfied with this status. Through their language, at times, they portray themselves as outsiders to some of the activities of the team, but like Pavlova, their comments about their roles with the team also contain references to personal accomplishment, satisfaction and solidarity with the team.

*Robotics and the Science Classroom: Reality versus Simulacra*

Expressions of ownership and solidarity are not the only area of student language through which students construct different worlds for robotics and the science classroom. In their interviews, all of the students spend some time talking about aspects of robotics that seem real, accessible and intense, while referring to experiences in science classes as contrived, vague and lacking intensity.

Because both the robotics and the classroom are social settings, it is not surprising that these discursive distinctions spill over into the language used by interviewees to describe relationships in the two contexts. Interviewees use distinctly different language in describing relationships with mentors and their teammates in robotics, and teachers and classmates in science class.

Some differences in how Shaggy Jones (SJ) refers to his physics class and his experiences in robotics classes have already been highlighted; however, there are more instances that merit attention. In a previously highlighted passage SJ answers the question, “Could you talk about your experiences on the robotics team and in a science class?” He responds,

> The . . . Well, . . . It- I think it- that would really depend on the teacher. Ms. Bruce has always given us, which is my physics teacher, has always given us plenty of hands-on stuff to do and it's just not as large of a scale, though. The robotics is much larger of a scale. But I mean, I can see how a lot of physics teachers or science teachers don't give you all the hands-on, you know, criteria that you need. (A[2-4])

Later, I asked for clarification. "So what do you mean by the stuff you do in physics is not as extensive, is that the word you used, [SJ: That's not the word, but that's the idea.] as what you do in physics [robotics]?" SJ answers this question with

> OK, then, the math and science is the same but the hands-on doesn't quite reach the same level then, the robotics we're working with we're cutting metal, molding, we're putting together a six-foot-tall 120-pound that could, I mean, if we don't follow safety procedures it's more drastic than if you don't follow them in the teacher's classroom. In the classroom you use the 1.5-volt batteries and it's just not as real. In robotics we work with these huge motorcycle batteries rather than the dinky household batteries. And the wiring we're working with wiring that has to support, you know, many more volts, 10 times as much volts or current as any wiring you have here in class. You…the mechanics if it's the arm it comes around and hits you it could break your arm. When you're working with little teeny fan motors in physics. (C[1-3])

The important elements of this response are the words that he employs to highlight a difference in scale between labs in his physics class and the robotic project.

One reading of SJ's comparison of what he does in physics class with what he does in robotics appears to be simply a comment on the scale of undertakings. "Ms. Bruce has always given us, which is my *physics* teacher, has always given us plenty of hands-on stuff to do and it's just *not as large of a scale,* though. The *robotics is much larger* of a *scale*." (A[3]). When working with equipment in physics class it is "*dinky* household batteries" (C[3c]), "*little teeny* fan motors in physics." (C[7a]) and "*1.5 volts*" (C[2b]), while *in robotics* it is "*six foot tall 120 pound*" (C[1i-1j]), "*huge* motorcycle batteries" (C[3b]), "*many more* volts, *10 times* as much volts or current"(C[4c-4d]) and "it could *break your arm*" (C[6d]). I interpret these as more than comments on the scale of the two undertakings. I interpret these as contrasts between something that is seen as authentic and useful and something that is seen as trivial and less useful. Both "dinky" and "little teeny" are more than just indications of small size. They connote things that are derisively small. SJ is not working with stuff that is simply larger; he is working with things "six foot tall 120 pound" "huge" "10 times as much volts or current," where not following safety rules could lead to "drastic" consequences; a robot arm out of control "could break your arm." This argument becomes even stronger when considered alongside two other excerpts from SJ's interview.

In another part of his answer about the differences in physics class and robotics class, he explains why experience with robotics is an advantage to someone wanting to study engineering. He says.

> You might like all the concepts; the physics about it, but you never got a chance to get hands-on with the mechanics or electrical. You can do all the book-smarts and everything about it. (B[3a-4a])

In the course of the passage, he draws a distinction between theoretical knowledge, "the concepts," the "physics," and "the book-smarts," and practical application of knowledge "to get hands-on." This distinction by itself does not reinforce my argument that classroom knowledge of physics takes on a new dimension in its application to the robotic project, but in conjunction with a later statement dealing with his contribution to building the robot, SJ explains:

> I didn't have too much to do with electrical or programming, but my knowledge has grown on especially how to use the things I learn in school; I ***actually put them somewhere***. I ***actually use*** that math. The Pythagorean Theorem or Ohm's Law, we call it Pythagorizing, ***actually*** moving that into something, ***we use it.*** Who ever needs to know what the hypotenuse of a triangle is until you think about the robot can only be this tall, and that's the best way to find its starting position because the

> hypotenuse is the longest part, so we ***actually*** have a place to use those applications. (L[8-11])

Here, the interesting features are the constructions that employ *actually*. SJ uses these to draw a further distinction between the nature of learning in the science classroom and learning with the robotics team. For SJ, classroom science learning has a particular quality in school that is distinct from its quality in the discursive space that is created in robotics. In that space the knowledge is "*actually used*"; it is *really used*; there it is *realized* or *actualized*; it is transformed from a theoretical entity that can be used to calculate a solution to a problem in a book, on a test or a lab exercise, and becomes a potent instrument for what SJ regards as real-world action.

In his descriptions of activities in science class and in robotics, Stretch Armstrong (SA) more faintly echoes themes highlighted by Shaggy Jones. To the question, "Can you compare what you do with the robotics team with what you do in your science class?" SA responded. "Uh, um it still has the same basics as a science class but it takes it a few steps forward to actually applying those science skills." I requested elaboration. 'Could you talk a little bit more about the 'couple of steps forward' and 'applying the skills?' Stretch elaborated,

> In the basic science class you'd learn the basics of physics; what can do this; what can do that. Then in robotics, uh, you're actually putting together, you know, you're using the basic laws that you learn to try and, you know, build the best robot you can. (B[1-2])

Here, as with Shaggy, SA emphasizes the actualization of potential as he moves the knowledge from class in the form of the "same basics" (A[1a]) "the basics of physics; what *can* do this; what *can* do that," (A[1c]) to robotics, where he "takes it a few steps forward to actually applying those science skills" (A[1b-1c]).

*Genuine Inquiry Versus Knowing Winks and Nods*

Several student interviewees use similar language in drawing distinctions between the robotics program and science classes. Some of these passages draw distinctions between the relationships that students have in these different contexts. Others, refer to the levels of authenticity that students perceive in the activities that they do in science classes and robotics.

Pavlova Kinsky (PK) compares the way that she works with her robotics teammates and her lab partners in science class, saying,

> Some things are similar. In lab you have to make sure that things get done on time and that nobody gets dumped on with all the work. But what we do in robotics is more intense, we're doing it on our own because the robot is a bigger project than labs are and what you start with in lab is clearer and more certain than building a robot. In lab, you always start with a clearer idea about how to get to the goal than in robotics. Labs are always connected to what you've been learning about all year. The lab is a way to help you realize what's important about what's been going on in class. So you can, you know, get it. In robotics we have to be more creative and innovative. It comes down to getting ready for competition. There's a lot of real tension and excitement that you don't get in lab. (G[1-10])

I followed this response with the question, "Could you talk about the roles that science teachers play in the science classroom and the role that sponsors and mentors play in robotics?" PK responded,

> In science class the teacher and the students have a good idea about how it will go. Particularly the teacher because he has taught the class so many times. You've got resources that the students and teachers can use, like the textbook and the handouts and stuff. The teachers guide you to where you need to go, using what they know and the resources. But in robotics club, you, we, a lot of it we have to find out on our own, like whether it will work. Because it's a new robot every year, experience that we have, um, uh, like adults and returning robotics members, doesn't count as much, it's pretty much like a new problem for all of us. No one's positive of the outcome, like when you do a lab. Labs have been done before and they know what the outcome should be. You can generally just straight up ask some teachers how to do it and many of them will tell you. It's like in science lab, the teacher doesn't really expect you to do much thinking.

> Robotics is all about thinking and research. You want to get a good grade in lab, but if you fail a lab it's no big deal for anybody. In robotics there is a lot on the line, and it would be awful if we built a robot that failed. (H[1-13])

In these passages there are some of the same sorts of bigger/smaller distinctions that were present in SJ's comments, but for PK, I interpret them as really being about the relative sizes of the two undertakings and not a discursive resource for comparing the relative worth of the two activities. PK's comments address differences that she sees in the sort of commitment that is required for doing science labs and designing and building a robot for the FIRST competition. PK views labs as useful but not authentic activities. She comments, "The lab is a way to help you realize what's important about what's been going on in class. So you can, you know, get it." (G[7a-7b]). But she says that, for her, and certainly for the teacher, the outcome of the lab activity is a foregone conclusion. Further, even for this student who will apply to and reasonably expects to attend Wesleyan University, Earlham College or Boston College, a good grade in lab is desirable but not nearly as crucial as building a robot that works.

For PK it seems that the nature of inquiry in science class is different from inquiry in robotics. The goals of the inquiry in science class are, it seems, to make sure that the work is completed on time, with fair apportionment of the responsibilities for those involved. A good grade is desirable, but a failing grade is "no big deal."

The inquiry process is not genuine. Everybody involved has a pretty good idea about the outcome because "the teacher and the students have a good idea about how it will go; particularly the teacher because he has taught the class so many times" (G[1-2]). What is more, "You can generally just straight up ask some teachers how to do it and many of them will tell you. It's like in science lab, the teacher doesn't really expect you to do much thinking" (G[9-10]).

In robotics, "It comes down to getting ready for competition. There's a lot of real tension and excitement that you don't get in lab" (G[10]); and what about failure? Well, "[i]n robotics there is a lot on the line, and it would be awful if we built a robot that failed." (G[13]). Inquiry in robotics is genuine for *all* involved, even the sponsors and mentors. "you, we, a lot of it we have to find out on our own" (G[5c]), and

> [b]ecause it's a new robot every year, experience that we have, um, uh, like adults and returning robotics members, doesn't count as much, it's pretty much like a new problem for all of us. No one's positive of the outcome, like when you do a lab. (G[6-7a])

For PK it is as if the inquiry in science lab is a game-like simulation of the inquiry in robotics.

This view is even more pronounced in Philemene Aaron's (PA) interview. In response to a question PA has mentioned that robotics was "way more intense and more difficult than it would be in a science class." (E[1d-1e]). I followed this comment with, "What was the source of the intensity? It was intense, why?" PA responded.

> It's not something that you learn how to do in school. Labs are always about stuff in the classroom that you're already learning about. You have a better grasp on it, I think. In class you're supposed to already know what you're doing. (F[1-4])

I followed this response with another line of questioning. "How would you compare the role of a science teacher with the role of a sponsor or mentor with the robotics team?" PA responded,

> Like I said before, in both places the teachers or sponsors help you, but in robotics you have teacher help, but it's different teacher help. In robotics you don't know and neither do the sponsors. In robotics we are all working from nothing. (G[1-3])

I probed, What do you mean by “working from nothing”? PA responded,

> It’s like the teacher in science class pretends not to know; sometimes they don’t even pretend they don’t know how it will turn out. But in robotics none of us really know how it will turn out. The robot comes out from only our ideas. In robotics the teachers are acting as more of a guide through all of this. Really, I think that they are more important, and really more involved with us than teachers in science. (H[1-5])

These comments are similar to Pavlova’s. There is the notion that somehow the students and the teachers do, or at least should, know how labs are going to go. After all, “you’re supposed to already know what you’re doing” (F[4a-4b]), and “It’s like the teacher in science class pretends not to know; sometimes they don’t even pretend they don’t know how it will turn out.” (H1a-1d]). Here the notion of inquiry in the science class as simulation is extended by involving the teacher as an accomplice.

PA’s comments on the genuine nature of inquiry (Martin-Hansen, 2002; Kelly, et al., 2000; Kittleson & Southerland, 2004) in robotics are also similar to Pavlova’s, but PA’s emphasis on the creative aspect of inquiry in robotics is even greater. Speaking of the outcome of the team’s efforts, she says, “In robotics you don’t know and neither do the sponsors. In robotics we are all working from nothing” (G[2-3]). Later she rejoins the theme and notes, “But in robotics none of us really know how it will turn out. The robot comes out from only our ideas.” (H[2-3]).

Hans Fowler, one of the more taciturn interviewees, expressed opinions along these same lines. To my question, “How would you compare what goes on with the robotics team with what you do in a science lab? HF responded:

> That’s a good question. I guess in a lab, everything is set forward, it’s what you have to do is in front of you. You may figure out a few things, but the end result is, you know, is given for you. You follow the rubric and fill in the data tables and the teacher gives you a good grade. With the robotics team we’re basically starting from zero, from square one, and going from there and ending with a robot of some kind. (G[1-5])

As with Pavlova and Philemene, HF says, “I guess in a lab, everything is set forward, it’s what you have to do is in front of you. You may figure out a few things, but the end result is, you know, is given for you” (G[3]). He argues that science labs are largely cookbook affairs that only occasionally require thought and creativity. In science class, all he need do to be successful is to “ follow the rubric and fill in the data tables and the teacher gives you a good grade.” (G[4]). In robotics, he feels that there is less certainty of success and, as a result, more creativity and ingenuity are required. He notes, “With the robotics team we’re basically starting from zero, from square one, and going from there and ending with a robot of some kind” (H[5]).

The tone of Hope Wedgwood’s interview is lighter than that of the other students who were interviewed, but she expresses some of the same points. She answers the question, “How would you compare the relationships that you have with your robotics teammates with the relationships that you have with classmates in your science class?”, with

> Well, um, we um, with people in robotics we felt very, very unified, especially with our cool camo and stuff, and we were like really a cool team, like, I guess we were cooler than all of the other kids who were too lame to be in robotics! In a science class all of the kids are doing it for a grade, where robotics is for fun. (H[1-4])

I followed with another question: “So, how would you compare the relationship that you have with your robotics sponsors and mentors to those that you have with your science teachers?” HW replied.

> Well, um, our mentors were helpful and um, I’m going to start with teachers, OK? The teacher, um, you have kind of student teacher thing where they know what you don’t know and they know how things will turn out. They are there to instruct you about what you don’t know, so you’re supposed to learn about what they tell you and our mentors were trying to get us to think it through and, um, well, get it on our own most of

> the time. So, I don't know, I think, well, um, the mentors want us to be more independent because we are supposed to do everything (I[1-5]).

In interpreting HW's comments it helps to know that the competition uniforms for the team were camouflage pants with team logo W.A.R. t-shirts (**W**ild **A**bout **R**obots). In the first excerpt, HW structures her distinction between robotics and the science classroom around lame/not lame or cool/uncool polarities. These distinctions are interesting because HW's characterizations of them appeal to Discourses that I certainly never have thought of when I consider the sorts of students who participate in an academically oriented extracurricular activity. Her statement, "with people in robotics we felt very, very unified, especially with our cool camo and stuff and we were like really a cool team, like, I guess we were cooler than all of the other kids who were too lame to be in robotics!" The utterances contain references to symbols of affiliation employed by "cool" kids like students in social cliques or gangs! She employs these distinctions again when she uses them to attribute values and motivations to students who occupy these groups. The "kids who were too lame to be in robotics," these "lame" kids "[i]n a science class … are doing it for a grade"(H[2]). The cool kids in robotics are in it "for fun" (H[3]). These distinctions aside, HW's comments, contrasting the classroom kids "doing it for the grade" in activities where the teachers already know how things will turn out, with the robotics kids who are doing inquiry working independently and getting it mostly on their own, retain the superficial-versus-the-real distinctions drawn by other interviewees in this section.

In the second excerpt, HW's discussion of these differences takes a more familiar tack as she discusses activities in science class and robotics. As with the other students, she characterizes science classes and robotics very differently. Science classes are teacher-centered. The relationship between the student and teacher is a “kind of student teacher thing” (I[2c]) that is based on the fact that “they know what you don’t know and they know how things will turn out” (I[2d-2e]); and when students and teacher interact, “They are there to instruct you about what you don’t know, so you’re supposed to learn about what they tell you” (I[3]). In robotics, on the other hand, the mentors are present, but the activities are centered on the team members. HW tells us “our mentors were trying to get us to think it through and, um, well get it on our own most of the time. So, I don’t know, I think, well, um, the mentors want us to be more independent because we are supposed to do everything” (I[4-5]).

Faith Wedgwood (FW) is in agreement with her team members on some of the differences between science class and robotics. During the interview, FW talked about the closeness of the relationships that she had developed with her robotics teammates. Wanting her to elaborate on this, and I asked, “Would it affect the way a science class works to have similar close relationships among classmates in a science class?” FW replied:

> Um, in a science classroom, I actually think it might be kinda distracting because you would feel more like talking, and in science class that wouldn’t work. Um, I mean if you got off on a tangent in a lab that would take away from, especially if it was class, but maybe it might work some. The goals of science classes and things like robotics are different. In a science lab type thing, especially, if it’s in school, then the goal just seems like to get it done, to get it down on paper and to do what you are told and just get it over with, um, but in robotics, um, well, I think it helps that we were all there, um because we were interested in robots and so, it depends; I guess if it were an advanced class it would be like you were there because you wanted to be, but if it were like just a required course or something, that it seems like the goal would be different and to just get it over with. So [pause] that’s it. (O[1-6])

FW expressed ambivalence about the benefit of classmates' being good friends. Many teachers share FW's reservations! In FW's case, the source of her reservations is clear when her views of the goals of science class are considered.

If, as HW has it, the goals of a science class are "to get it done, to get it down on paper and to do what you are told and just get it over with" (O[4e-4g]), then any sort of social interchange would be undesirable. FW differs from some of the other interviewees because she does not talk about the creativity or intensity of the inquiry required for success in robotics. Instead, she talks about the close relationships that were formed among robotics team members.

In an earlier portion of this chapter Patrick Pitcher's strongly divergent opinions of learning in science class and learning in robotics were reviewed. A synopsis of my construal of his views is that robotics is a project with clear goals that is centered in the team of students, while activities in science class have vague or less meaningful goals that are centered in, or controlled by, the teacher.

In this section of the chapter the analysis of data has produced a number of findings. The analysis of language has shown that all of the students who were interviewed gave accounts that highlighted differences between the activities they have experienced in their science classes and these they have experienced in robotics. When students who provided samples of language during the robotics competition were interviewed, there was a marked convergence between their interview descriptions of activities in robotics and the interpretations that I have constructed from the language that was captured during those competition activities.

In their interviews, all of the student participants described robotics as an environment where students have rich and meaningful relationships with their teammates, and solve real-world problems, working with mentor help and working independently. In solving problems, they employ basic scientific knowledge in conjunction with creative inquiry. Many of these same students variously describe activities in science classes as teacher-centered, trivial, contrived or somewhat vague and, like their relationships with their classmates, deficient and meaningless. All of the student team members marshaled distinctly different discursive resources when describing activities in science classes and in robotics.

Female members of the team used language that cast them as outsiders to certain activities. They variously identified certain activities as better suited to girls and others as better suited to boys. In referring to invitations to join in on one of these activities, the robot build, several female members of the robotics team emphasized their status as outsiders.

## Origins of Student Discourses

Discourses are not simply language. They are language plus its interaction with all of the other things that make up culture. So, when it is noted that a group or a member of a group enacts a particular Discourse, what is being noted is how the language that is being used interacts reflexively with various elements of context, to do particular kinds of cultural work. If students involved with the robotics team enact a particular Discourse in conjunction with their involvement with the team, it is important to understand what elements of context are activated by the team members' language and what elements of context reflexively give meaning to the language.

*The Roots of Student Ownership and Solidarity*

Using an analysis of student language that drew on sociolinguistic theory centered in Gee's (2001) notion of Discourse was applied to samples of language collected during robotics team activities and from student interviews, I have made the argument that student participants in this study use language that indicates a strong sense of ownership and solidarity with their robotic team members toward their accomplishments as members of the robotics team. In contrast with the language used in reference to the robotics, the same students do not employ the language of ownership when referring to their involvement in the science classroom. What are the reasons for these contrasting uses of language? What elements of context that underlie or produce these differences? In examining these questions I shall refer to the transcripts of student and mentor interviews.

*Collaboration through Brainstorming*

*PP's account: "No one says, "I'm the boss, so, we'll do it like this"*. First, I examine PP's interview transcript. In explaining how the brainstorming sessions about the robot design were conducted. He explains,

> First, there were ideas that we discussed. There were lots of ideas (D [5a-5c]).
>
> You just give your idea, and somebody gives another idea. Then we discuss it (E [6a-6b]).
>
> You say this is my idea. It's good because we can build a robot that will do something that's good. Someone else will say, "Yeah, but mine will do this and it won't cost so much or it is simple and won't fail." (D [7-9])
>
> We argue and discuss. We put our ideas out, and try to say why ours has an advantage or something. Sometimes we can field test, but we didn't have much time. Mostly, we argue and give reasons for how we think about it, and why we think that way (D[10-13]).

The passage is an account of dialogic argument similar to that in the in-pit crew transcript. In response to this question, I pointed out that PP had said that “there were lots of ideas” but that the team built only one robot. I asked, “But, how did you finally decide?” PP’s response was,

> [W]e don’t really vote. There’s never much time. We just decide, but when we decide no one says, “I’m the boss, so, we’ll do it like this.” Everyone doing design gets to say. (VII[14-18])

These passages are an account of the same sort of dialogic arguments that are recorded in the pit crew transcript. In this account PP seems pretty certain about how he and his teammates presented arguments for and against various elements of design for the robot. However, when it comes to recounting how the team settled on a final design, the only thing he seems sure of is that no one pulled rank and said, “I’m the boss, so, we’ll do it like this.” His account is a description of a process that was multivoiced and collaborative from start to finish. Since I wasn’t present during this process, my guess, based on the similarity of this account to others, is that the group reached some sort of consensus about the design. At any rate, whatever the process, the accounts all center on a collaborative process among the team members.

Scott Bruce’s account mirrors the students’ account of brainstorming. In comparing the students’ approach to problem-solving by engineers, he makes references to the importance of brainstorming for both the engineers and the robotics team. Commenting on brainstorming, SB notes that

> The purpose of brainstorming is really twofold. First, it’s the source of the best ideas. Also, you get everyone to participate. Even if somebody doesn’t have an idea, they feel like they own the idea when plans are finalized. Engineers do that, too. (AIII[49-51])

In his account of brainstorming ideas for the robot's design, PP described the open give-and-take that characterizes dialogic argument. SB recognizes that this discursive act is a route not only to innovative ideas but to building ownership in a project, as well.

This account of decision-making in the context of the robotics team is more informative when it is contrasted with PP's answers to questions. I asked, "What sort of help do the engineers give the students that are on the team?" PP answers that

> [w]e all know something and we have to put it all together to finish and get it right .All of the stuff has to be finished on time. They give a lot of help. We don't know much about building really big stuff. We don't have a lot of experience. Some of us have built small stuff. Some of us have worked on or built RC cars or planes. Mr. Bruce and Mr. Pacelli really design and build stuff. We have ideas. They help us see what's easy, what's possible, what we'll need to build something, how much the parts will cost. The robot project is big. It's not like science class. (I[23-34])

As several other students did, without previous prompting, PP compared his science class experiences to some aspect of robotics. This intertextuality is noteworthy when considering the origin for project ownership and team solidarity because it shows that, even when they are not prompted to comment on it, there is a comparison of experiences in robotics with those in science classes. As a follow-up to PP's answer to the previous question, I asked, "You mentioned science class. Can you tell me more about what you do in science classes, how would you compare science class with robotics? Could you talk about something that you did in science class that was hands-on and similar to robotics?" PP answered "Class is really different. You never know where it's going or what's it's about." I was perplexed by his answer and asked PP, "Do you mean that you don't know what you're supposed to do in lab, or that you don't understand the directions?" PP answered (K[38)]) "Not really.", and he explained:

> I can understand the directions, and I know how to fill in the charts and stuff. But with robotics we agree on a design; we know what the robot has

> to do. We test the robot some. We know when we have to finish. We know when we are finished. With science class you don't have something like the robot. Things are not clear. You don't really know what's the point. You know when it's due and that you're done when the teacher says, and when she takes it up to grade. (K[38-45])

PP's account of science class is interesting; he did not talk about a "hands-on activity." The account is also devoid of any mention of collaboration. Instead, he talked about activities that appear to have aspects of cookbook labs, such as charts that are filled in. "I can understand the directions and I know how to fill in the charts and stuff" (K[39]]).

After this brief answer to my question, PP returns to a comparison of activities in science class to activities in robotics "But with robotics we agree on a design; we know what the robot has to do. We test the robot some. We know when we have to finish. We know when we are finished." (K[40-43]). Again, this account centers on collaboration.

It seems that PP sees activities in robotics as anchored in the efforts of the group, as indicated by his consistent use of "we" and in the goal of building the robot, as indicated by, "But with robotics we agree on a design; we know what the robot has to do. We test the robot some. We know when we have to finish. We know when we are finished." (K[40-43]). His statements about science class are not clearly rooted. He employs "I" (K[39]) when he responds to my call for clarification of his answer to the previous question. However, in the third part of his response, as he returns to comments on activities in science class (K[44-45) PP, *the one who doesn't know* "what's the point", *is the indefinite "you."* In this comment, he literally loses "self." PP comments (I really feel that he laments the fact): "With science class you don't have something like the robot" (K[42]). This comment is significant because it gives meaning to the final utterances in this passage: "Things are not clear. You don't really know what's the point.

You know when it's due and that you're done when the teacher says and when she takes it up to grade."

The robot, the focus of the team's collaborative efforts and the yardstick of group accomplishments, is missing in PP's recollection of his science class. It is replaced by activities that, for him, do not seem to have a point and that apparently lack any metric of accomplishment separate from the teacher's timetable and grade.

PP's account portrays robotics as a project with a clear goal that is, in many important ways such as planning and execution, centered in the collaboration of the team of students, while activities in science class have, in his view, vague or less meaningful goals that are centered in or controlled by the teacher.

*Power: Choice versus Compulsion*

One of the most prevalent features of the student team members' language during interviews is the way that they employ language to talk about the voluntary nature of the robotics team as compared to the required involvement in their science classes. Since Critical Theory always deals with differences in power, this theme in the analysis of the students' language is the one the most essential to a critical discourse analysis.

*"We chose to be here."*

Reexamining a previously quoted passage from Shaggy Jones' interview transcript, I discovered an interesting excerpt that speaks to similar issues of ownership. In it, SJ makes a comparison between safety issues in robotics and in science class. He comments, "I mean, if we don't follow safety procedures it's more drastic than if you don't follow them in the teacher's classroom. In the classroom you use the 1.5-volt batteries and it's just not as real."(C[2a-2c]). The case for the importance of the shift between the “we’s” of robotics to the indefinite “you’s” of classroom activities was made previously. This shift is all the more trenchant when placed alongside a student’s comment about performing activities “in the teacher’s classroom.” [SJ, C(1n-1p]). In science class, at least in SJ’s view, he is in “*the teacher’s classroom.”* This might just be an expression that could be disregarded as something that arose by chance, until it is put in the context of SJ’s response to an initial question and several follow-up questions that deal with a comparison of relationships that he has with robotics teammates and science classmates. This is a long segment of the transcript that runs from Questions E-I.

During an answer to a question about relationships formed in science class and in robotics, SJ makes a comment about the excitement that comes with the beginning of robotics season. As a follow-up question, I asked, “Do you see the first day of school as being an equally auspicious time to start relationships and make new friends?” His response was

> “Oh no no. The first day of class is always very stressful, you get all that paperwork that you gotta do. I think it’s because you are forced to be in class; we’re not forced to be in robotics. You’re in class; you gotta do what you’ve gotta do. You have to do well or you’ll be there again.” (G[1-6])

I followed this response with another question, “You mentioned that you have to be there. Does that dynamic affect the relationship with your teacher in class?” SJ requested clarification, “You mean Ms. Bruce?” I clarified the question, “I mean, I’m interested in Ms. Bruce, too, but she’s the robo-queen, so in addition to her, cast your mind back to your other science teachers, as well.” SJ’s response was,

> In robotics I’m not having to be there; I’m choosing it, to be there working on that project. If I don’t want to come back, I don’t have to come back. I go to school every day because I have to be there. I actually enjoy it, but most people go because they have to be there. And so the teachers that you meet at school or the teachers that you have, you’re forced to get along

> with whether you like it or not and after school's over you have the choice to go home or go hang out with any of your other friends from school, but when, when robotics comes around, I have the choice to go home, or hang out with those other friends from school, but I choose robotics because I enjoy the people that are there because I choose to be there. (H[1-5])

I think it is clear from part of his response, "I go to school every day because I have to be there. I actually enjoy it, but most people go because they have to be there," that SJ would be at school even if he were not compelled to be there. But it is also clear that it is important to SJ that he has a choice where robotics is concerned. This is true for the majority of the students on the robotics team. At some point in their interviews, a majority of students who were interviewed, , make comments about the voluntary nature of robotics and the fact that science class is part of a system that requires a certain number of credits in core areas and compels them and their classmates to be in class.

During his interview, I asked Patrick Pitcher (PP) the question, "How would you compare the relationships that you have with your classroom science teachers and the relationships that you have with the robotics sponsors?" He responded, "In some ways it's the same. Other things are different." I probed, "Can you say more?" He continued,

> It's hard to say, but mostly you don't know science teachers as real people. You don't have time. Teachers are there to teach you. You don't work with them. You just do the stuff that they give you. You need three units of science, so you take chemistry. They have to be there and so do you. In robotics, sponsors, it's really different. We are there because we want to be; all of us, the students and the adults. You could play a sport or be in drama or go home and hang. So could the sponsors. (M[47-57])

PP comments on the circumstances that bring students and teachers together in school science classes, saying, "You need three units of science, so you take chemistry. They have to be there and so do you." He contrasts this arrangement with the voluntary nature of robotics "In robotics, sponsors, it's really different. We are there because we want to be; all of us, the students and the adults. You could play a sport or be in drama or go home and hang so could the sponsors."

In addition to PP's take on choice, this passage contains another comment on the teacher-centered view that PP takes toward his science class: "Teachers are there to teach you. You don't work with them." PP 's view of science class is of a class where the only one with agency is the teacher. The teacher acts on the students by teaching them, and giving them activities to do, but the students do not influence or act in concert with the teachers.

Philemene Aaron (PA), a female student who attended the robotics competition as a scout and promotional specialist, answered my question, "How would you compare the relationships that you have with people in your science classes with your relationships with members of the robotics team?" She responded

> The kids on the robotics team are definitely brighter and more into it than kids in science class. We all have a common interest. In science class; they may not care about the topic at all. In science class you're thrown in with whoever. You know, robotics is voluntary while classes aren't. You have to take chemistry, so you take chemistry. Because robotics is voluntary, it's more likely that you'll get along and work well with the people than in class. ([I[1-7])

In PA's account she speaks of how she values the voluntary aspect of robotics. As she sees it, it encourages bright, enthusiastic people with common interests to come together to work toward a common goal. She, too, makes reference to the compulsory nature of school classes.

All but four of the students on the robotics team take Advanced Placement science classes when an appropriate one is, and if none is offered, they take honors-level science classes. These are the sorts of students who, if the state did not compel attendance, have parents who, in all likelihood, would make certain that they were in school. However, the majority of them speak of the significance and value that they find in the voluntary aspect of robotics versus the compulsory nature of school classes.

*Talking turns: Taking turns and power.*

Lemke (1990) uses conversation analysis to look at relationships and power in science classes. In this analysis, he looks at who talks, what is being talked about, how often students talk and how often the teacher talks and in what order they talk.

I did not perform such an analysis in this study, but I was interested in an analysis of the pattern of turns. In an earlier section, I showed how the mentor's interactions with the boys created a discursive space that facilitated talk which aided in the solution of problems with the robot and the formulation of strategy for future competition. He did not speak often, but what he said, when he said it, and how he said it provided an element of context that insured that the students maintained a sense of ownership in the project.

## Moving Between Worlds: Mentor Language

The second guiding question deals with how the context of a pedagogical approach facilitates the Discourses enacted by students and teachers, and, in this case, mentors. In the previous sections, I have examined the language that student participants used in association with their experiences learning science in the science classroom and as members of the robotics program. I have argued that student participants use linguistic resources to construct very different orientations in relation to their science-learning activities in the robotics program and in their science classrooms.

The next section will focus on a similar analysis of the language of the two mentors who participated in both phases of the study, and how the reflexive interactions of their language and the context of robotics facilitated the enactment of their Discourses.

As noted in Chapter Three, the mentors come from different backgrounds. One is a veteran professional mechanical engineer and the other is a veteran classroom science teacher.

Both mentors have the respect of the other members of the robotics program. Their statuses in the group are a result of their credentials, their history with the group and their age. These are bolstered by the group's understanding that their leadership helped to get last year's team to nationals and this year's team's to the regional competition with a functioning robot.

The FIRST Robotics Challenge is designed to be like real-world science and engineering, but the student team members are neither scientists nor engineers. They are being introduced to the practices of the scientific and engineering communities that contend with the realities of insufficient time, money and challenges to expertise. They are learning how people fail and succeed in the world of those realities. The mentors introduce them to this world and guide the students along this unfamiliar way.

The key to understanding the actual roles of mentors lies in revealing how Scott Bruce and George Mitchell employ language as they meet the challenges of the robotics project and talk about these challenges in relationship to the other aspects of their engineering and teaching lives. In meeting these challenges and talking about them, both mentors use language to construct different discursive spaces in reference to the robotics program and their professional lives as an engineer and a teacher.

*Returning to the pit.*

An earlier section considered the language used by the pit crew as it diagnosed and repaired the robot after the first practice round was considered. This earlier analysis centered mainly on the language of the student members of the pit crew, and how their language demonstrated a sense of group ownership for the robotics project and a sense of solidarity with one another as they pursued the project's goals. The language that engineering mentor Scott Bruce (SB) used in the context of this group received some attention, too. In the earlier analysis, I began to develop an argument for how SB's language demonstrated his position of leadership within the group as its mentor, but without closer analysis of SB's language, it is not clear how SB does his job or views his role as engineering mentor.

In this section, I will clarify these points by focusing on the way that SB used language, and I will further develop the argument that, as mentor, he used his language to prescribe and guide the activities of the pit crew, while giving the students in the group space to develop their own ideas about the robot's problem, its repair and the ramifications of the repair on the robot's post-repair capabilities. In focusing on SB's contribution to these exchanges, I think it is important to consider that SB made only 31% of total utterances and was responsible for 24% of the total clauses in the transcript. By these numbers, he hardly dominated the exchanges, but here, I contend that the numbers do not tell much of what is important to this story. This noted, after returning to the pit, SB began the exchanges, and the nature of his opening comment framed the rest of the exchange.

*Language in context: Engineering mentor in action.*

This section returns to the transcript of language from the pit after the first practice round. To foreground the exchanges in this transcript, I think it is important to note that as the team rolled the robot back to the pit, I observed the crew talking, but because of the incredible din that is part of a FIRST competition, I was unable to capture these exchanges. Therefore, I do not know what was said in the time that the pit crew walked from the competition area to the pit.

When the crew arrived in the pit SB declared that traction would be the topic of the exchange. He did this, however, with a soft subjunctive command: “All right. Let’s talk about traction” (1). The jussive subjunctive is a way of making a soft command, and can be contrasted with stronger commands or declaratives such as, “We’re going to talk about traction.” The softer form anticipates a certain consensus about traction’s having been a problem for the robot in the first practice round. In their first utterances Patrick Linemannn (2a) and Patrick Pitcher (3) confirm the consensus.

SB’s next utterance (5) referred to the universal wheels, and took the same form as his first utterance ‘Let’s swap these . . . .’ While he uses the same soft subjunctive sort of command again, I regard this statement as having the same effect as SB’s having said, “Change the wheels.” As he made the suggestion the general inspection of the robot ended; it was lifted onto the workbench, blocks were placed under the chassis to make the wheel assemblies accessible, and the pit crew moved to get the tools to remove the universal wheels. SB continued with instructions for the modification, “. . . like we did in the field test.” While these were instructions, they relied on the rest of the crew, PL, PP and others who joined them for the actual wrench work, to remember what was done at the field test. SB’s second utterance ends with a claim about the likelihood that the modification will solve the problem. SB ends as he began, in the subjunctive mood, “That may be the ticket.”

SB’s third utterance (10) is an answer to PP’s question, “Are the wheels getting the same torque?” The form that SB uses for his answer is structurally different from the form that is most common in English. He reverses the standard order of the clauses and omits a subordinate conjunction and in his answer. His answer, “Guys, the way it is geared I can’t see how the wheels could get different torques.” would more commonly be, “Guys, I can’t see how the wheels could get different torques because of the way it is geared.” In this utterance, the subordinate clause (10a), “…the way it is geared…” is treated as background information. SB has assumed that all of the crew can agree with this. It must be so; the crew is standing there looking at the arrangement of the wheels and the drive train. The independent clause (10c) is the foreground information; it is SB’s assertion that, in their present arrangement, the wheels could not receive different torques. In foregrounding information, the speaker is declaring that the information is something that he/she is prepared to discuss or argue (Gee, 2005; Halliday & Matthiessen, 2004). However, this is not all that SB achieves with utterance (10).

SB does two additional things with the second clause (10b), “I can’t see how . . .” One way to approach the function of the clause is as an argument for the assertion that, as they are arranged, the wheels are getting the same torque. This analysis stems from considering who the “*I*” is. The students in the pit were aware of the status of the speaker. For the crew, SB is the person with authority stemming from his mentorship, credentials, professional reputation, demonstrated competence and he can be seen as having the function of communicating, “It’s so because I say it’s so.” However, SB softens the authoritative weight of the assertion (10b). He does this by placing emphasis within the clause on “…see…” rather than on “I… .” In doing this, he invites empirically based counter-claims and de-emphasizes the authoritative weight of the clause. He invites the rest of the crew to say whether they can see how the wheels could receive different torques, given the arrangement of the wheels and drive train. This analysis becomes stronger if SB's statement is compared to other possible statements that communicate the same ideas, such as, "There is simply no way, no how, that the wheels could be getting different torques" or stronger yet, "Any fool can see that, with the way that they're geared, the wheels have to get the same torques." These have the same logical function, but they do not invite different opinions.

Finally there is the term of address, "Guys…," which functions in three ways. Even though SB is addressing PP's question, it is a call for general attention, but it is also a way of making what is essentially a rejection of PP's contention (8b) to the entire group rather than to PP specifically. It is also a play for solidarity with the group that contrasts with other possible calls for attention, such as "Knuckleheads…" or simply "Hey… ." These would call the group to attention, but lack the element of solidarity communicated by "Guys."

SB has the last word in the exchange. Utterance (13) begins with a question (13b) to the pit crew, "Any other ideas?" The question is followed by a pause about 1.5 s in length. Given the form of SB's previous utterance, I regard this question as a genuine request for different ideas. Alternatively, it might be nothing more than a notice to the group that discussion is finished, or SB's attempt to insure that that everyone feels included. If this interpretation is adopted, SB's request stands in contrast to "That's it," or an utterance (13) that completely omits 13(a).

Utterance (13b) begins with a minor clause: "OK." This clause is important because it is reflexive to (13a). It is short form for, "Since there are no questions…." It serves as an acceptance by SB of permission from the group to move on with the modifications to the robot. The permission might be seen as something along the lines of, "Then, by your leave, let's move on." I have separated (13b) and (13c), but they can be regarded as a single unit. Again, SB uses a soft subjunctive rather than some form of imperative. Clearly, he is making a bid to have the crew make the modifications that are needed for the new tires and the new drive train. This ends the exchanges between the members of the pit crew.

Throughout the transcript, SB uses his authority to set the agenda for the group and to move the group toward actions that will improve the robot's performance. Through his language he also portrays himself as a leader who values the opinions of the group and who is careful, while exercising authority, to maintain his position at the head of, but within, the group.

In SB's professional life he is an engineering project manager, so he has the technical background that he needs to be an engineering mentor. His performance as mentor in the pit demonstrates a deft balance. He shows great sensitivity as he balances the need to prepare the robot for the next round of competition, while being mindful of the students' needs for discussion and meaningful participation. However, the episode in the pit gives no hint of the difficulties that SB experienced as he embarked on his first tenure as engineering mentor to a group of teens.

*Becoming a mentor: Moving between two worlds.*

The transcript of an interview with Scott Bruce from 6/17/08 gives some insight into the issues involved in this transformation. To understand SB's notion of mentoring, I feel that the best place to begin is with his account of his first impressions of the students whom he worked with in 2007, the first year of robotics for High School #1 and #2. My first question to Scott was, "Just in general, what do you see when you see these kids confront the problems of designing and building a robot?" His response to this was, "Um, we use an expression called stunned mullet or clubbed catfish. Like, like, they just don't know what to do." The students did not know what to do with him, and, as the rest of his account shows, he did not know what to do with the high school students that he encountered.

> And I had to learn in the first year that, um, the kids are really children in grown-up bodies. Ok? I didn't understand that. I didn't appreciate that. I probably understood it on some level, but I didn't internalize it, until I began to realize kids on the robotics team need order; step-by-step orders. If you give them [only] an objective, I thought that we could do business this way. (AI[4-10])

Clearly, SB thought that the students could and would work independently and that they had skills that he subsequently discovered they did not possess. Here is his account of what he found when he tried to work with the high school students in the first year of the robotics program.

> If you give them an objective, I thought that we could do business this way. The objective is design a piece to do this function, to fit here. I draw a sketch, organize two or three kids that seemed interested. (I didn't ask anyone to do anything that they didn't want to do; Right? Or at least I didn't perceive that they didn't want to do it) and, uh, and I would then march off and find another group and say we need to make this piece, or say we need to assemble these parts or program this function for these components. (AI[10-16])

If the preceding quotation is compared to part of SB's answer to a later question, Question C, where he described managing professional engineers, it is clear that that he expected to be able to deal with the students in a way similar to the way he worked with engineers whom he managed.

> Like an engineering manager, that's what I do. As a manager my work is to get work done through others. Not to do it all myself. It would kill me. Nothing would get done. There is a lot about what I do with the sixty engineers that I manage; many of them [who are] 25-30 year veterans of nuclear power that is the same as what I do with the robotics team. I say, "OK, guys, here's the objective. They say, "OK." We brainstorm for a while. We write it down. We revisit it. We do walk downs. We talk to vendors. We try to get a better understanding (snaps fingers) and then we're done. I'm done. They know what to do, and they go do it. It takes about six months to a year. (BI[42-58])

He was surprised by the students' response to his requests.

> And I would come back and I'd find that they were either lost and dazed or not interested. They'd want to play with their video games, or, ya' know, pick up pieces and just twiddle with 'em and play. So I had to learn how, speaking from my perspective, of course (AI[17-19]).

SB was not the only one who was crossing between worlds. On the basis of their accounts of their science classes, the students were accustomed to being acted on by their teachers; they were accustomed to being given something to do. Being a self-starter was not what science classes were about. Clearly, the students were crossing over from their accustomed worlds to another that will have different rules and will place different demands on them from what their science classes do.

Two teachers, Elizabeth Bruce and Lenore Pacelli, sponsors of the robotics team, came to SB's aid.

> Elizabeth, Lenore and yourself already knew all this. And it was probably amusing for you teachers to watch me try to get the kids to do things. Ms. Pacelli finally said, "Scott, they are kids in grownup bodies," and Elizabeth finally said, "It's OK to yell." (AI[20-22])

Through his language, SB paints a picture of an outsider, someone from another culture, with different practices and values. He doesn't know how to negotiate the obstacles that confront him while working with high school students. He is a manager of engineers, not a mentor to high school students. Eventually, SB comes to understand how to work with high school students.

> It takes mentoring! It took me a while to figure out just exactly where the kids were. Then, I was struck from year one to year two how different they were (AI[27-29]).
>
> And it came down to, uh, literally marking, uh, raw materials to cut, drill, attach, screw one: every, every little teeny step at a time. And if you stay with the kids, and, and just kept 'em focused almost like a procedure. Following a mental procedure which emerged organically, as we went because there wasn't time to design on paper. To write detailed instructions. "OK, now it's time to, umm, drill a hole!" "OK, now what?" So, you know um, that's my perspective. That the kids you know have to have a set of detailed instructions, if you can which is very difficult in the FIRST Program. But drive, drive in that direction and the kids will follow. Slowly they get better. Slowly they get what we're about and what has to be done (AI[38-43]).

Two things about these passages are striking. First there is the contrast between the amount and type of detailed involvement that SB described as he guided the students through their work. This is lacking in his account of managing professional engineers CI[42-48]. In fact, he refers to withdrawing from the group after the details of the project are sufficiently understood by everyone; "We try to get a better understanding (snaps fingers) and then we're done. I'm done. They know what to do, and they go do it." CI[45-48]. Second, referring to his experiences with the robotics team, he said, "It takes mentoring!" I wonder why he did not choose the word "managing" or something less strong? Does SB toss these terms around at random, or are they indicative of different ideas situated in different contexts? In a description of the similarities of the robotics program to real-world engineering, SB comments on how he tries to make the students' experience in the program as much like the world of engineering as possible.

> The most fun is in solution development, in reconciling all of those objectives and constraints. The robotics program is a microcosm of all of this, reconciling all those objectives and constraints. I try to inject as much of this into the process as I can, not by telling stories. The project provides the basis for all of it. I try to do it by acting like an engineer (BI[34-41]).

He ends by saying that he tries to make it real by "acting like an engineer," "not by telling stories" about engineering or about being an engineer. He does this in the context of the robotics program that serves as a microcosm of the world of engineering practice. SB is drawing a distinction between making representations of what a thing is and presenting *that thing* in a way that the students can become directly involved. As an engineering manager, he deals with individuals who are already comfortable with the world of engineering; with its ways of coordinating and being coordinated, its technologies, symbol systems, places, ways of being, such as acting, interacting, feeling, emoting, valuing, gesturing, posturing, dressing, thinking, believing, knowing, speaking and listening. It would be unfair and unreasonable of him to expect the same from high school students, given their age and backgrounds. So, as an engineering mentor, it is his job to guide the uninitiated into these ways, not by telling them how it is, but by showing and involving them in ways that it is done. His focus as a mentor is not managing the output of a group but introducing students to the Discourse of Engineering. In doing this, SB is concerned with authenticity. As he says, "I am learning how, how *to speak* in terms that they'll understand *without sacrificing*, you know; we're still talking about objectives and, an', scientific principles and how to get there step by step" (AIII[35-36]).

*Constructing an Engineering Mentor Discourse*

SB's narrative of becoming a mentor is a narrative of coming from the engineering community to the community of high school teachers. In his account, he relates how he acquired fluency in different ways of ways of, quoting Gee (2005, p. 22), "coordinating and being coordinated by other people, things, technologies, symbol systems, places, ways of being, such as acting, interacting, feeling, emoting, valuing, gesturing, posturing, dressing, thinking, believing, knowing, speaking and listening." His is a story of moving from a Discourse with which he was very comfortable to a Discourse that was, in many ways, alien, perplexing and frustrating. It is an account of coming from a discursive outside to a discursive inside. It is an account of learning that he is not going to "do business" [AI(10c)] with the robotics team members; he is going to be a mentor to them.

The Discourse that he enacts as a mentor is an amalgam that melds the engineering manager and the high school teacher. His account of coming to grips with effectively mentoring the robotics team is filled with instances of learning and applying ways of acting, speaking, valuing, emoting, etc., that would be at odds with practices that would be effective or acceptable in his role as an engineering manager. Still, his role as mentor positions him with one foot in Engineering Discourse and one foot in Teacher Discourse. In this role he is able "to inject" [CI(38a)]: that is, bring, from the outside to the inside, authentic engineering practices into the robotic program. I have used the transcripts of SB's account of becoming a mentor to the robotics team and his language in the pit to construct his Mentor Discourse. This Discourse and the transcripts of the language from which it was constructed become a plausible explanation for why SB did not simply return to the pit and give orders to change out the wheels, and at the same time, why he did not choose a more open-ended approach to diagnosing the robot's traction problem.

*Contrasting Student Discourse With Mentor Discourse*

The transcripts of SB's language indicate that he is invested in the team's competitive success; however, his relationship to the project is not the same as the students'. Yes, he uses his language to move the team toward the repair of the robot and make to it more competitive but not at the expense of his mentees' opportunity to experience important aspects of science and engineering. His language and involvement are those of a mentor, not a repair shop manager.

For SB, the project is his, but for him the goals of the project are different from the student team members' goals. For the students, the goal is the robot and the competition results. He is committed to helping the students learn the rudiments of engineering practice while advancing their scientific understanding. Because of his different role in the project he employs his language in the pit very differently from the students'.

*Moving Between Worlds: The Science Classroom and Robotics*

In this section, I will focus on George Mitchell (GM), the other mentor who participated in the study. The data for this portion of the study are different from that used for the other mentor, Scott Bruce. Because of the timing of the study and the schedule of the robotics design and build activities it was not possible to record instances of language involving GM in these processes. At the competition GM was mainly involved in making sure that students got shuttled to and from the hotel to the competition venue, and to and from on-site and off-site events. His role kept him in almost constant motion in and out of the extremely noisy venue. When he was at the venue, he was in the stands. All of these factors made it difficult to capture audible stretches of language from him in the competition setting. Therefore, all of the data for GM is taken only from a recording of an interview.

In their interviews, the team sponsor, George Mitchell (GM), and student members of the robotics team draw very similar distinctions between activities with the robotics team and activities in the science classroom. GM is a highly regarded chemistry teacher with more than 30 years of teaching experience, with a background in industry as a quality control chemist. He has coached/sponsored FIRST robotics teams for 12 years. On the basis of his interview, one must conclude that he views his role in robotics and in the classroom very differently. To illustrate these differences I will employ several excerpts from GM's interview.

*A view of different worlds: Sponsor versus classroom science teacher.*

The first excerpt is taken from part of GM's lengthy response to my question, "Could you talk about how you feel your role as a teacher in a typical science class compares with your role as a robotics sponsor?" Adopting the terms of the question, GM referred to himself as a classroom "teacher" and robotics "sponsor." He opened by saying that

> …you are more of a facilitator [in robotics] than a teacher…. I think the first part of the process is getting to know the kids, and being more comfortable with those kids, it's a more relaxed atmosphere, um, it's not as official, if you will, as being a teacher, and, um, you're there primarily to help these kids to use the tools that they need to use, uh, you're there to help them think about problems, to more than anything what I try to do is just ask questions, "Will this work?" "What do you see wrong with this?" (A[1b-5])

GM continues in a later passage, speaking of his role as facilitator as “to sit back and watch the kids discuss, [or to] draw (A[6b & 6i-6k])…. [M]entors function as sounding boards, as well, uh, refiners of ideas, and sometimes referees for discussions. In these roles they facilitate discussions.” (H[3a-3b]). Going further, GM attributes an understanding of these differences to the students in his classes, saying that

> I like to develop a relationship with all of my students, but it is much easier to do it in an environment where the students don’t feel or see you as a threat and I don’t, uhh, I don’t know that threat is the right term. In the classroom, I think that they feel that the teacher is in charge, the individual in charge and as teacher that’s traditionally what we refer to them as, and uh, it’s very hard to get these students, they don’t relax as well. It just often, uhh, comes down to the grades they make and the test scores. Um, I think it’s years of exposure to the idea that the teacher is “the boss,” the head, the authority. (C[2-6])

In contrast to his characterization of his role as a facilitator, GM feels that because of “grades” that students make, and “test scores”, that his students view him in authoritarian terms. His account of the classroom is of an atmosphere in which his students and he are in opposition, and unable to form the sorts of relationships that are possible in robotics. So, his use of “sponsor” and “facilitator” connote more than a simple difference in function. GM uses them to set the stage for a dichotomy that is present throughout his interview. They set the stage for his characterization of the science classroom and the robotics team as different worlds, populated by different sorts of people with different values, participating in different activities and with very different goals.

The excerpt below comes from GM’s response to a follow-up to the previous question, “You mentioned that you felt that the atmosphere for robotics was ‘more relaxed’ than it was in a science class and that your role as a robotics sponsor was ‘not so official.' Could you talk more about the reasons for those differences in the robotics team and the science classroom?" GM responded:

> Well, I think the traditional expectations of students is changed in the robotics environment, I think that they see it completely differently from classroom science. I think traditionally the students expect all knowledge to spout from the teacher and that's something that's very hard to overcome in the science classroom, although I think that there are some of us that attempt to get past that point with'em, and if we could, they would realize that they are responsible in some meaningful way for picking up information and finding out things and that they need to work toward that, whereas in robotics, uh, I don't think that they look to, um, to the mentors as much in that sense as they do as a source for simple advice in what they are trying to do. Um, one of the things that I really like about the program is that you can get those kids doing things that they have never considered doing, working with power tools, wiring the robot, for some, using new software, or doing programming. I think that the biggest surprise for me in my first year as a mentor was how few of the kids knew how to use, say, a power drill and had never even considered using one. And from my standpoint, I think this is a great program because these are things that kids need to know how to do. They're goin', they should know how to use power tools or start a gasoline motor, not that we do that in robotics. This program is not in a virtual world; it's not vicarious; it's real. This is all part of a program where the kids have to figure out the answers to real-world problems. It's left up to them to negotiate answers to the problems as a group. It's also very interesting to watch these kids, uh, meld into a team and see who your leaders are. I think in many cases when you know the robotics kids as a teacher, you get some big surprises as to who comes to the front in the robotics environment as compared with the classroom. Uh, many times, the most capable high-level physics students disappear in robotics, and kids that are lower-level science student and with a reputation as a gearhead will shine, when it comes to robotics (B[1-16]).

As with the student members of the robotics team, GM characterizes the science classroom and the robotics team as different worlds, populated by different people. Both he and the robotics team members highlight this dichotomy through an emphasis on the contrast of real versus unreal as they speak of robotics and the science classroom. From the previous excerpt, "This program is not the in a virtual world; it's not vicarious; it's real. This is all part of a program where the kids have to figure out the answers to real world problems." (B[11-12]) and from another section of the interview, discussing limitations and pressure built into the FIRST program, “And part of the, uh, reason, I think that part of the reasoning with the robotics program is to teach doing more with less, which is kind of a realistic approach to life and business”(A[10]). In a statement about the similarities between the robotics program and the work done by practicing scientists, the dichotomy between the real-world nature of robotics and the less authentic world of the science classroom emerges again. GM comments:

> Well, I think the robotics does, partially because of the imposed deadline, the limits placed on the kids by costs. In a sense, um, thinking back on what we worked with the students in chemistry, they have absolutely no sense of urgency when they are trying to work through these things - for example, learning the polyatomic ions. We create an artificial deadline where we say, you must know these, but we tend not to say this is why you need to know these and throw them into a situation where they have to figure out what those polyatomic ions are. Um, and because of the imposed deadlines the kids understand that they have no choice. They know that they have to ship the robot, good, bad or indifferent by the completion date. Um I think that’s more real-world than the classroom would be (F[1c-6]).

To emphasize these differences, GM speaks of a transformation in students’ attitudes as they participate in robotics: “…traditional expectations of students is changed in the robotics environment; I think that they see it completely differently from the classroom science.” (B[1-2]). He says that the students’ traditional view of the classroom is one where “…the students expect all knowledge to spout from the teacher” (II[3b-3c)], and he contrasts this view of the classroom with one of robotics, where “…in robotics, uh, I don’t think that they look to, um, to the mentors as much in that sense as they do as a source for simple advice in what they are trying to do” (B[5b-5e]). In this excerpt, GM speaks of students’ view of the classroom as a place where they passively take in knowledge that is dispensed by the teacher, while in robotics the sponsors and mentors take a less central role in providing advice, teaching real world skills, and observing the processes that the team members devise to jell into a team that negotiates answers to problems. Compared to their passive classroom counterparts, the students on the robotics team are active and efficacious.

These themes continue as GM describes the satisfaction that he takes as he sees the robotics team members learn and tackle their challenges. GM contrasts the willingness and flexibility of the robotics team members with students in his classroom, whom he finds rigid, close-minded and lacking initiative.

> For the college prep track student they, uhhhm, they want to know how to do it; they expect you to tell them how to do it; and they aren't even willing to consider the possibility that there's more than one way to approach a problem. Whereas, in robotics the kids do generally show respect for other people's opinions and other ways of doing something. They will find, the robotics kids are willing to accept that. In a classroom, generally speaking, from years of teaching experience, I've actually had students get mad with me when I would show them that there is more than one way that they could do this problem. I try to get them to understand that what you need to do is look at, um, I don't know what word I want to use here, look at how you function and how you see things and then build your problem-solving method on what you already have and understand, rather than take your style and adapt it to what I do. We all have a style. Part of your learning experience is to find and develop that style. And many students just absolutely hate that. (C[9-18])

During GM's interview, he is the only one who is talking, but there is a lot that he attributes to the thoughts of his students about their experiences in his science classes. He is for practical purposes placing his words in his students' mouths. At no point does he say, "This is what my students think about my science classes, but they have gotten it all wrong!"

The closest he comes to denying the validity of these attributions is his comment about the students' feeling that the teacher is a fount of knowledge in the science classroom (B[3d-4]). He comments, "… that's something that's very hard to overcome in the science classroom, although I think that there are some of us that attempt to get past that point with'em, and if we could they would realize that they are responsible in some meaningful way for picking up information and finding out things and that they need to work toward that ..." (C[3d-4]).

GM's statement is not a denial of his perception of the students' view; rather it is a weak statement about attempting to combat the perception. His statement uses the subjunctive that is used to convey a wish or a condition that is contrary to fact " . . . some of us that *attempt* to get past that point with'em, and *if we could they would* . . . " With this he expresses his and his colleagues' inability to address what he sees as an undesirable situation. There are no students on the robotics team from GM's current classes with whom we can compare GM's account of his classroom and how his students perceive it. So, in the absence of a strong statement to the contrary, the view of the science classroom that he attributes to his students is, I contend, really GM's own view of his science classroom.

*Different worlds: Different Discourses.*

A prominent feature of GM's account is the regularity with which he speaks of the young people in his science classes as "students" and the young people on the robotics team as either "kids" or "robotics kids." This is natural, of course! The "kids" in his class are "students" and the "kids" on the robotics team are "students" in the high schools from which they come; however, I can find no instance in GM's interview where there is a "kid" in one of GM's classes or a "student" on the robotics team. Why? Because in these different contexts, these young people, as GM says it, are enacting different Discourses. They are inhabitants of very different discursive spaces. As GM and the students encounter one another, to the extent that within these different discursive spaces they establish identities through their different language, activities, values and goals, both GM and his students certainly enact different Discourses. More importantly, in these different contexts, they become, in an important way, different people.

*Comparing Student and Mentor Classroom Discourses*

The accounts that the robotics team members and GM give of their experiences of the team's activity and of science classes are no more than that, and the result of analysis that I have applied is no more than my use of an analytical approach applied to transcripts that I made of language that I recorded. Having noted this, I find it striking that the young people and adults who occupy such different social positions on the team and in science classes give such similar accounts of their experiences in both settings. My construal of the students' and GM's accounts may not be reality, but if they are not real, in building these accounts they nevertheless employ uncannily similar discursive resources and approaches.

*Discourses and Power in the Classroom*

*Issues of compulsion.*

For GM and the students, the classroom is a place where they lack control. For both, power comes from outside of the classroom. For the students the principal issue is grades and the science credits that come with these grades. Student accounts comparing robotics to their experiences in the science classroom speak to both the students' and their teachers' being compelled to be in the classroom. The students' view is that they need a certain number of units of science credits and the teachers are assigned to teach them in their science classes.

*NCLB, standardized testing, and curriculum.*

For GM, issues pertaining to covering the curriculum and standardized testing are the principal means through which power is projected into the classroom. These points are also on the minds of some student robotics team members and the non-teacher mentor Scott Bruce, too.

Scott Bruce (SB) is curious about the classroom. Near the end of his interview, he turned the tables and posed a question to me. He asked, "Do you see the kids expressing the same sort of ownership for activities like labs in their science classes?" I responded, "No, not at all. They view the process in science class as different from robotics and the relationships that they have with their science teachers as different from their relationships with their robotics sponsors and mentors." To this SB responded:

> It strikes me that, uh, that science class is highly repetitive. In other words the lesson plan, there's certain, there's certain first principles that have to be taught. Gravity pulls things down, heat generally makes temperature go up, right? Chemicals combine in certain ways. Whatever it is. All right and that's what you're there to teach to a large extent. Um, so it's a knowledge base, right? Um, so it's, it's a knowledge domain. You want the kids to be a little bit higher up in the knowledge domain. Any ability to develop solutions, to be analytical, to solve problems and that sort of thing is important, but, uh, is that really important in the curriculum to the state tests and so forth? But with robotics you're given [none] basically, they unveil the objectives and you have six weeks to not only develop a solution, but to build it, test it and operate it. It feels like you're creating something from nothing (D[1-16]).

Once again, SB is not a teacher. He is, however, married to an outstanding physics teacher, Elizabeth Bruce, who is also one of the sponsors of the robotics team. He is also the father of a member of the robotics team who attends HS1. First, his statement indicates that, as he views it, the goals of the science classroom might be at odds with a program such as robotics. It appears that he views the learning goals of the science classroom as centered on factual knowledge, what SB refers to as "a knowledge domain"

(D[11]). He contrasts this view of the science classroom with his view of learning in robotics that he sees as centered on problem-solving and creative design.

There is no way to know what factors inform SB's ideas about classroom science, but it is interesting that he mentions that he feels that learning activities in science classrooms are somehow ultimately constrained by forces from outside the classroom. SB mentions "the lesson plan" [D(2b)], a *teacher-made* plan that SB views as defining classroom activities. About learning science in the classroom he says, "It strikes me that, uh, that science class is highly repetitive. In other words, the lesson plan, there's certain, there's certain first principles that have to be taught"(D[1-3]). Discursively, at least, the lesson plan should be an element under teacher control. It is, after all, teacher-made. Ultimately; however, SB sees the activities in the science classroom such as "the curriculum … state tests and so forth" [D(14c-14e)] as defined by elements beyond the teacher's control.

Shaggy Jones (SJ), a student from High School #2 and a member of the robotics team in 2007 and 2008, makes comments about the science classroom that are similar to SB's. While speaking of the differences between activities in the science classroom and in robotics, he notes that

> [y]ou can't just take six weeks out of the curriculum and do a project 'cuz you won't get what you need done and so you have to do the couple-of-day labs, one, two, three maybe a week, at most, but never a six-weeks project, and that is why we can't do robotics in class, at the moment (D[3]).

It is not possible to know if Shaggy thinks of the curriculum as something that is handed down from on high, or whether he thinks of it as something devised by his science teachers. I know that SJ has taken several Advanced Placement science and mathematics courses, and I am certain, as a teacher of those classes myself, that students are well aware that the curriculum is set by someone outside of their classroom. Regardless of SJ's notions about the origins of curricula, it is clear that he views projects such as those from robotics as at odds with the important goal of covering the curriculum.

George Mitchell more explicitly identifies an outside influence on the activities in the science classroom. To a question about the difference in the patterns of relationships and interactions between students and teachers, GM responded that he felt that these differences occurred

> because of the amount of material the students are expected to learn. Um, especially now with No Child Left Behind, um I think that most teachers feel incredible pressure to make sure that their students do well on the high-stakes testing that is a part of No Child Left Behind. Uuh, The pressure to cover the topics makes it hard to give students, uh, time to experiment and, and fail and uh, and I think that to some extent we should do that in science more than any other class (E[1b-3]).

Because GM is a classroom teacher, it is not surprising that he more specifically names these influences. He names No Child Left Behind (NCLB), a national education policy associated with neo-conservative political theory, as the source of the broad curriculum, and the pressures of "high stakes testing" that are part of assessments of Adequate Yearly Progress under NCLB.

*Power in the Classroom: Reflections of Conversations.*

It is interesting that three interviewees with such different ties to education have identified such similar extra-classroom influences on science learning activities. This indicates that there is a widely and well known conflict between Discourses that favor open inquiry learning, typified by FIRST Robotics, and the sort of learning activities that dominate the typical public high school science classroom under NCLB. This sort of conflict is what Gee (2004) refers to as a capital “C” Conversation, a debate motif that is widely known within a society and is characterized by particular language practices that are well known to individuals on both sides of the Conversation.

## Summary

The students, their sponsor and their engineering mentor in their interviews use language to construct a science classroom that is unreal and inauthentic, a place where no one who actually occupies the classroom has power or in any meaningful way exercises agency. In opposition to this view, through the language used in the context of the robotics competition and in their interviews, the students and their engineering mentor construct a discursive space where they experience authenticity and agency.

# CHAPTER 5

# DISCUSSION

The focus of this research was a group of high school students and their adult mentors who participated in an extracurricular robotics program that designed and built a robot, and successfully competed in a regional robotics competition. The purpose of the study was to examine how, in the course of participating in this program, the students and their adult mentors used language to construct their identities. Discourse analysis was applied to transcripts of language from video recordings made in the context of the robotic team's activities, and from semi-structured interviews. The guiding questions for the study were as follows:

1. How do science teachers and their students enact Discourses as they teach and learn science?
2. How does the pedagogical approach of a learning activity facilitate the Discourses that are enacted by students and teachers as they learn and teach science?

The study and its guiding questions were motivated by the language of two key educational reform documents, *Inquiry and the National Science Education Standards* (NRC, 2000) and *Science for All Americans* (AAAS, 1990), that call for students to learn science through inquiry and, in doing this, to experience what it means to be a scientist. These reform documents are not simply prescriptions for the use of certain kinds of science learning activities. They call on students to adopt the habits, values and language of scientists. This union of particular habits, values and language are what Gee (2001) refers to as a Discourse.

Previous studies of science learning (Jimenez-Aleixandre et al., 2000; Roth & Bowen, 1995; Roth & Lawless, 2002; Roth & Lucas, 1996; Roychoudhury & Roth, 1996; Warren & Rosebery, 1996) have established that there are conditions which favor inquiry, but little has been done to elucidate how student and teacher language is used in constructing the Discourses that are part of inquiry learning.

FRC challenges students' and mentors' theoretical and technical capabilities through an open-ended task. This task provides real and meaningful opportunities for students, with help from adult mentors, to direct the progress and outcome of an extended scientific and technical undertaking (FIRST, 2009). It embodies the essential elements of student-centered inquiry that result in students' behaving like scientists.

Answering the study's guiding questions has added to science education literature in two ways. First, it has established how language was used in the construction of student and mentor Discourses in the context of the open inquiry that was part of this study; and, second, it has identified the elements of the study's context that contributed to the construction of these Discourses. Both of these results have implications for classroom practice. They will help classroom practitioners identify the elements of their own classroom learning contexts that facilitate the construction of Science Discourse. They will also make them cognizant of some of the elements of language that are sometimes part of Science Discourse in the science classroom.

## Discussion of Findings

Analysis of the study data has resulted in several conclusions. Each conclusion will be presented and discussed in light of the study's underlying theoretical framework. This will be followed by a discussion of the study's implications for science education practice, and extensions of this study that might be pursued in future research. Finally, I will make personal comments and reflections on the research that is presented in this dissertation.

### *Conclusion One*

Elements of context that are part of FRC are not currently amenable to most public school classrooms in the United States. In the case of W.A.R. these elements contributed to the student participants' enactment of Scientific Discourse that are set out in the goals of AAAS (1990, 1993) and NRC (1996, 2000). These elements are the real world nature of the problems presented by FRC; the degree to which student team members exercise control over, and ownership of, the project and its products; and the role of the mentor in the structure of FRC.

#### *Real-world problems.*

FRC contributes to the enactment of Scientific Discourse through the project's context. One element of this structure is that FRC presents students with extended problems the solution to which really requires Science Discourse. As the students work to solve these real science and engineering problems, mentors who are already participants in this Discourse support them. This results in the students' seeing themselves individually as scientists/engineers and the group as a community with the potential to successfully solve scientific and technical problems.

An example of this is the pit crew's and the team's engineering mentor solution of a traction problem with their robot at the March 2008 FRC. In this situation, the pit crew worked with their mentor to diagnose and fix their robot's traction problem. This was a real-orld problem that required the student team members to employ scientific and technical terms in making claims about the cause of the traction problem, as they argued about the best fix. This situated use of language and the pattern of argumentation that the team employed were typical of practicing scientists (Gee, 2005; Toulmin, 1958). If an activity does not necessitate this type of situated use of language, students will perceive it as just another classroom exercise to be worked through, just like the others before it (Duschl & Osborne 2002; Jimenez-Aleixandre, 2000; Mueller, 2002; Watson et al., 2004; Zack, 2002).

Another feature of the FRC project that lends it to the enactment of Science Discourse is the extended time over which the project occurs. The six-week Build is an extended time when compared to the requirement that classroom inquiry be limited to a couple of 50-minute periods. The extended time is required because building a functioning robot is intricate and involved. Time flies for those involved in the intensity of the six weeks of FRC Build. Still, FRC is not restricted by the requirements of a school curriculum to cover a particular set of topics in a particular time in preparation for particular sort of test. The extended nature of the project is an element of the project that makes it a real world problem.

*Ownership of the project.*

There are a number of features of the FRC context that fostered a sense of solidarity with teammates in their efforts and ownership of the project and its products.

These elements of context facilitated the enactment of this aspect of Science Discourse. One of these features is the way that FRC incorporated mentors into the structure of the project.

This element of context extends to another element of FRC that makes it a real world experience that really requires Scientific Discourse: the mentor's relationship to the problem that is presented by the project. The mentor's relationship to the FRC project was very different from a classroom teacher's relationship to a lab exercise. Unlike classroom lab exercises, the mentors, who I argue play a role similar to that of classroom science teachers, are on an even footing with their student collaborators. Neither the mentors nor the student team members know the solution to the problem that the project presents. This is another feature that makes FRC a real world science/engineering experience. The mentors' relationship to the problem is a means through which student members of the team gain ownership of the problem and its solution. By this I mean that when the teacher presents a problem to which the he or she knows *The Solution* (emphasis added), this is the teacher's problem, and when the teacher insists on *The Solution* (emphasis added), the solution is the teacher's, too. Which by contrast, the mentor's relationship to the project was essential to W.A.R.'s experience in FRC. It resulted in a power shift within the group that is hard to achieve in the classroom, and opened the door to student ownership of the project (Bernard, 2003; Roth & Lawless, 2002; Roychoudhury & Roth, 1996).

Another real-world element of FRC's context that contributed to the enactment of Science Discourse through ownership and solidarity by student team members was the voluntary nature of the program. Scientists and engineers do not wake up one day and simply find themselves doing science and engineering. They arrive at their positions as a result of the choices that they exercise in pursuing their education. As a result of their scarcity in the workforce, they continue to exercise elements of choice in the associations that they make and in the work that they do. In the same way, W.A.R. team members did not wake up one day and find that they were doing robotics. They chose to do robotics with a group of peers with similar interests. This arrangement runs counter to the W.A.R. team member's experience and accounts of science classrooms in science education literature (Lemke, 1990; Roth & Bowen 1995; Roychoudhury & Roth 1996).

Transcripts of student participant language are replete with students' expressions of ownership of the team's project and solidarity with their teammates in their joint efforts. The discourse analysis of these expressions connects them to, among other factors, the students' appreciation of the voluntary nature of FRC's context. The first of these themes is the manner in which student participants use language to express ownership of the team's project and express solidarity with their team members in their joint undertaking. This theme is apparent in the analysis of language collected during the robotics competition and in interview data. The themes of ownership and solidarity from language related to the robotics team stand in contrast to the themes and patterns of language that students used as they answered interview questions related to their science classroom experiences.

*The mentor's role.*

There is yet another feature of FRC that contributes to student ownership of the project and its products. While mentors do provide scaffolding for their mentees, another feature of FRC's structure that facilitates enactment of Science Discourse by student participants is the level of freedom that students have to determine the course that the project takes. This freedom extends from the robot's design to the way that the team portrays itself during competition.

As the student members of the pit crew worked to solve the robot's traction problem, their engineering mentor guided them through the process. The mentor's role was essential to this process. As the students were neither scientists nor engineers, and t the language, practices and values of these two groups were foreign to them, furthermore their mentor was a guide through the process of acquiring a facility in this new Discourse. The mentor's role is in the tradition of Social Constructivism, and is similar to the role that the mentor took in studies described by Roth (1993) and Roth and Bowen (1995).

The studies by Roth and Roth & Bowen took place in a different context from W.A.R.'s participation in FRC, where the studies occurred in a private high school in Canada where students were studying environmental science as part of a biology course. These authors propose a cognitive apprenticeship model for inquiry learning, wherein an essential component of the cognitive apprenticeship model is the role played by a knowledgeable person who is a member of the particular community of practice into which the apprentice is to be introduced. WAR's engineering mentor was such a person. His role is important at two levels. First, during the incident recorded in the pit, the mentor helped to focus the students' discussion of the traction problem on the problem's most likely cause and most efficacious repair. However, while directing the students, the mentor provided space for the students to argue and to plan driving strategies for the upcoming competition, based on the changed capabilities of the robot. This is the second level at which his involvement was important. The nature of his involvement allowed the student team members to develop a sense of ownership of the project's outcome.

As it relates to the conditions under which inquiry is likely to occur, this study does three things. It confirms what has already been established about the conditions under which inquiry is likely to occur (Arvaja et al, 2002; Jimenez-Aleixandre et al., 2000; Roth, 1993; Roth & Lawless, 2002; Warren et al., 2001; Woodruff & Meyer, 1997). Secondly, this study connects those conditions to a novel learning context. It also presents an argument for how that context and the language produced in it reflexively influence one another to permit science students and their mentors to enact Science Discourse. These findings from W.A.R.'s experiences of FRC are significant because in the light of the goals of AAAS (1990,1993) and NRC (1996, 2000), these findings open new possibilities for the ways that teachers and students might work together to institute classroom practices that achieve results similar to W.A.R.'s in FRC.

As it is currently and is likely to be in the future, science learning most often takes place in the classroom. However, the elements of FRC's context that seemed to be most closely identified with W.A.R. seem inimical to current classroom context (Baez and Boyles 2009; Boyles, 2007; Gee, 2004; Lemke, 2007). Currently, the science classroom context is controlled by centrally mandated curricula that are "a mile wide and an inch deep" (Baez and Boyles 2009; Boyles, 2007; Gee, 2004; Lemke, 2007). The goal of teaching these curricula is passing scores on centrally mandated high-stakes standardized tests that require, at best, only superficial knowledge of science. This approach to science education encourages teaching through skill and drill that encourages passive knowledge storage as a means of passing tests (Baez and Boyles 2009; Boyles, 2007; Gee, 2004; Lemke, 2007).

These elements do not allow for the time needed to replicate the elements of FRC that are important to promoting Science Discourse. They do not permit or require the sorts of associations among students and their teachers that replicate these elements of context. Finally, there are not many teachers in science classrooms with backgrounds similar to the W.A.R. mentors (Lemke, 1990, 2007; Roth & Bowen 1995), and where there are capable teachers, they are restrained by the mandates of overly broad curricula, endless preparation for high-stakes tests and the rafts of paperwork connected to teacher accountability. All of these elements of science classroom context restrict the implementation of activities like FRC. If the goals of AAAS (1993; 1990) and NRC (2000; 1996) are to become the classroom's goals, then science classroom context must change. Otherwise, large groups of science students who do not have access to programs like FRC will be at a serious disadvantage.

The importance of this finding is that these elements of Science Discourse are not just an artifact of the relatively brief competition period, but are the result of the broader context of the entire project's duration and all of the varied roles in which the student team members participate. Because of these factors, the real-world nature of the problems presented by the activity, the expert support of the mentor, and the genuine control exercised by the student team members over the project, activities such as FRC were a means for students with varied backgrounds, strengths and skills to engage in Science Discourse.

*Conclusion Two*

Through FRC, W.A.R. student team members formed and became part of a community of learners composed of their team and the wider world of FRC. This community is similar to the community of scientists in that it promotes knowledge and sound practices, provides structures for dissemination of information, provides support for research and development and encourages interaction of its members through free association. These are important elements because truly enacting Science Discourse means membership in such a community. Meeting the goals of in AAAS (1990, 1993) and NRC (1996, 2000) means involving students in a community of learners. Currently, it is uncommon for students in science classes in the United States to be a part of such communities either within their schools or within a broader context outside of their schools.

*It's not about the robot!*

To someone standing outside of FRC and looking in, it might appear that FRC is about building a robot. In fact, this study may have added to this notion by reporting the considerable time and money that were expended in building and readying W.A.R.'s robot for the competition.

This being noted, the analysis of the study participants' language has revealed the extent to which this language has been used to promote and portray intense personal relationships that were a part of participating in, and talking about participating in, robotics team activities. These relationships are the essential element of community. In light of this, it is ironic that this relational talk and sense of community arose from a group of people who built a robot, that icon of a cold, de-humanized world portrayed in so many futuristic novels. It is also noteworthy that the word "robot" appears infrequently in interview transcripts, and that little of the talk in interviews turns to topics directly related to the robot. Some of this orientation can certainly be attributed to the questions that were asked of interviewees; however, the nature of prompts notwithstanding, the interviewees were not restrained from talking about the robot. Still, they infrequently refer directly to the team's robot. Instead, their talk is about Robotics.

This is the same as saying, in the terms of Jimenez-Aleixandre et al. (2000), that the W.A.R. team's focus was not on Doing the Lesson, but on Doing the Science. Jimenez-Aleixandre et al. (2000) and other authors (Duschl & Osborne, 2004; Watson et al., 2004) note that students presented with a hands-on inquiry science learning activity frequently see the goal of the activity as a simple matter of setting up the apparatus, collecting the data, filling in the tables and turning in the work to be graded. For science students who approach inquiry in this way, their orientation would be on building a Robot and not on the principles of science/technology and the practices and values of scientists and engineers. As it is structured, and as W.A.R. characterized it, FIRST was about more than the simple process of building a robot. It is about participation in the processes, standards and practices followed by scientists and engineers in solving problems.

At every level, the study data indicate that Dean Kamen and Woody Flowers, FIRST co-founders, were correct when they declared that FIRST is not about building a robot. In the Kickoff addresses for the 2008 and 2009 FIRST competitions, both Kamen and Flowers talked at length about the organization's philosophy. They pointed out that the FIRST robotics competition is about high school students' becoming involved in an extended learning experience that promotes the development of creativity and innovation, science and engineering knowledge and skills, logistical skills, leadership skills, close relationships with their teammates and mentors, and networks with similar-minded teens. Their statements focus on the things that the participants should learn, but they place the learning and development of the skills in the context of a community of teammates and mentors, and networks with similar-minded teens.

NRC (2000) promotes and Bernard (2003) recognizes the merits of extended investigations, and both endorse them as a means of developing creativity. NRC (2000) acknowledges the impact that personal relationships between learners exert in effective construction of knowledge.

While the major policy documents have nothing to say about the essential role that logistical and leadership skills play in science and engineering projects, as someone who has won research grants and led months-long field investigations in an isolated area of the world, I can say, with absolute authority, that a failure in either of these essential areas means failure for such scientific research efforts. AAAS (1990, 1993) and NRC (1996, 2000) may not recognize the important link between the more academic pursuits of science and real world practical skills that are integrated into the practice of any profession: scientific, technical or otherwise; but Dewey (1916) recognized that the inclusion of these sorts of skills and understandings was an essential part of any education for a democratic society. The omission of these sorts of practical skills from these policy documents points to a particular philosophical orientation that was the foundation of these policy documents' production. This orientation is incisively problematized by Baez & Boyles (2009) and Lemke (2007).

*Communities promote knowledge and sound practices.*

The analysis of data provided several instances where the community formed among the members of W.A. R. set standards for knowledge and practices as they developed the robot, sought to correct mechanical problems that they encountered during competition and tried to come to terms with approaches to collecting and meaningfully interpreting data pertaining to the rounds of competition. These are all instances of the W.A.R. team community's setting their own standards for knowledge and practices. However, this aspect of a scientific community extends to the broader world of FRC.

An important instance of FRC promoting sound practices across the FRC community is found in the philosophy called Gracious Professionalism. Kamen and Flowers (2008) talked at length about this concept, the relational philosophy that FIRST promotes for interactions between teams. Gracious Professionalism is the philosophy that even in competition, FIRST competitors should assist other teams in every aspect of preparing their robots for competition.

At a practical level, Gracious Professionalism involves self-interest because, as previously discussed, in FRC teams do not compete individually, but as members of three team alliances whose make up changes with each round of competition. If a competitor's robot is functioning at less than its full potential, in one round this may play to your team's advantage, but in a later round the broken robot may be part of your alliance and thereby become a liability for you. Beyond the issue of self-interest, Gracious Professionalism also embraces the belief that a community trying to address a common problem benefits, when even competing solutions realize their maximum potential.

Gracious Professionalism also calls on more experienced teams to assist less experienced teams during Build by sharing design and engineering experience. It calls on more experienced teams to invite new teams to pre-competition events, where teams can test their robots in mock-ups of the real competition. In short, Gracious Professionalism is intended to promote a community where each member of the community, and the community at large, can realize its potential.

Both Gee (2004) and Lemke (2007) lament that this sort of involvement in a community of learners is not more often a part of learning in public schools. Both authors note that active involvement with wide communities of learners and practice involves both students and their teachers with real-world resources and experiences that are simply not part of education in public school classrooms at this time.

*FIRST community provides structures for dissemination of information.*

At the team level, W.A.R. disseminated information in a number of ways. Information went out through email. Department captains attended meetings and communicated information from those meetings to their departments. General informational meetings were held and attended by all of the W.A.R. team members. In addition, teammates would exchange information as they socialized.

At the larger level of community, there is the FIRST website that has a dedicated page for FRC that is maintained throughout the year. After the 2008 Kickoff, there were two websites that were intended to provide teams with information. One of these sites was a list-serve that was inaugurated and hosted by the Pontiac Central Delphi, an FRC team. This site, known as Chief Delphi, was a source for answers to all manner of technical questions, provided a forum for teams to discuss design successes and problems, get advice from robotics team members and professional engineers, discuss interpretations of game rules and to voice all manner of complaints about FIRST, poorly designed components and so forth. The other site was maintained by FIRST, and was intended to inform teams about the programming of computer-controlled systems that came as part of the FRC robotics kits. In a sense, this approach to putting less experienced members of a community of practice in contact with more knowledgeable members of the community extends the apprenticeship model of learning to a scale that was inconceivable prior to the Information Age.

*FIRST provides support for research and development.*

As with communities of professional scientists and engineers, FRC provides support for research and development. Earlier in this account, I discussed the rather substantial amounts of money that were required for W.A.R. to participate in FRC. In certain areas of the country, where there are large companies with engineering divisions or companies involved in the design or manufacture of high tech products, many routes to funding and engineering help are available to FRC teams. However, in small towns or rural areas without these resources, mounting an FRC team can be a challenge. FRC is aware of this, and has local representatives that place teams in contact with resources within their area, or in some cases, outside of their area.

Funding is a hurdle for all beginning FRC teams. Generally, FIRST places these teams in touch with the National Aeronautical and Space Administration (NASA) which provides almost every new team with its initial funding. This was the case with W.A.R. In addition to the NASA grant, through FIRST, many new teams are placed in contact with General Electric Corporation, Siemens, AT&T or General Motors. In April of 2008, Richard Bodor, Senior Mentor, FIRST, Atlanta, told me that in Georgia, he knew of no group that wanted to start an FRC team or Lego Robotics League team, a program that FIRST offers for middle school students, but had been unable to do so because of lack of funding.

As is clear at this point, good mentoring was an essential element that made FRC a valuable learning experience for the W.A.R. student team members. Here, too, FRC provides a network that puts teams in touch with businesses, universities, technical schools and interested individuals. Through these resources, teams are provided with mentors with backgrounds that have prepared them to assist an FRC team in learning to design and build a robot. In addition to these resources, W.A.R. team members found a machine shop that was owned by the father of a student who attended HS2. Both Lemke (2207) and Gee (2004) comment on how rare it is for public schools to make similar use of the resources available to them in their communities.

*FIRST encourages interaction of its members through free association.*

The founders talk so little about the robot because, as they claim, FIRST is not about robots. The FIRST program is deeply concerned with developing a new generation of problem-solvers, but they feel that this task requires more than teaching a set of skills to bright young people. The FIRST founders view problem-solving as something that is most efficiently done through social interaction. Throughout the organization's statements (FIRST, 2008; 2009) and in the emphasis on the role of mentors, the emphasis on relationships between teammates, the emphasis placed on building networks between teams and Gracious Professionalism, there are strong elements of Social Constructivism. Yes, the FIRST program is about science and engineering, but more than these, it is about how the impact of these disciplinary threads can be strengthened by weaving them into a particular social fabric.

In the analysis of data, themes associated with the voluntary nature of the robotics program were highlighted as a discursive means through which the student team members constructed their accounts of their relationships with one another and ownership of the robotics program. This character permeates the sorts of associations that are furthered by the structure of FRC. This is the sort of association that characterizes communities of scientists. Scientists and organizations that serve the interests of the scientific and technological communities maintain electronic means of association such as discussion boards and listservs. These entities also publish journals and periodicals that serve as a means of disseminating information about the activities of members of the communities that they serve. These organizations also sponsor and host conferences.

The electronic network that FIRST and its FRC teams maintain are important means to the associations that are part of FRC, but this is only a small part. The grandest opportunities for association are the competitions themselves. Here, there are some of the elements of professional conferences attended by scientists and engineers. As scientists and engineers present papers or lectures at conferences, they and their work receive a hearing that makes them better known in a more immediate and personal way. Part of professional conferences is performance, a sort of show-and-tell. This public performance component is also an aspect of FRC competition.

This public performance aspect of FRC places the students of the team and its mentors before a community of peers outside of their immediate and regular association. Watson et al. (2004) suggests that students resist, or simply do not see the need of, discussing or explaining themselves before an audience of classmates and a teacher who already know full well what their activity has been or what result their work has achieved. In the Watson et al. study, students did not explain their activity and results to investigators, who had been in the classroom during the activity. However, they eagerly explained, at length, both of these things to visitors who had not been present during the activity.

To their peers, the FRC competition is full of discursive acts. Yes, the FRC team members actually discuss and explain what they have done, but the competition places the discussion and explanation into another discursive mode as the robots take to the field of play.

If, as NRC (2000) explains, an aspect of inquiry is to display solutions and to explain and account for results of the inquiry, then this approach includes the requirement for this sort of performance. As Pavlova Kinsky commented, “You want to get a good grade in lab, but if you fail a lab it’s no big deal for anybody. In robotics there is a lot on the line, and it would be awful if we built a robot that failed” (H[1-13]). Her comment suggests that the aspect of public performance, long hours of work, sizable expenditure of resources and just ordinary pride in the group’s efforts place a burden on the group to do their best work and place it before an association of peers. Bernard (2003) reports similar findings in his study of students involved in doing science projects. This sort of free association among peers is rare in public school science classes, much less among schools within districts or across the nation (Lemke, 2007).

Science and engineering are not delimited by the practitioner’s bench. They are neither delimited by the group with which a practitioner may work, nor by the broader institution of which a group may be a part. Science and Engineering Discourse takes place within a worldwide community that is characterized by particular practices and structures. If students learning science in public school classrooms are to have a chance to participate in Science Discourse, then their experiences cannot be solitary and delimited by their lab areas and the walls of their classrooms. Instead, their Discourse must be part of a broader community of Discourses that takes them and their efforts beyond the bounds of their classrooms and schools. Students who do not benefit from the broadening experiences that FRC provided the W.A.R. team experience a narrow, depauperate and consequently inauthentic version of science.

*Conclusion Three*

The science classrooms of the W.A.R. student team members and their faculty mentor's accounts are discursively deficient and broken. This emptiness is constructed through the elements of the student team members' and mentor's accounts of the science classroom that place the value of the classroom's activities beyond the science classroom's spatial and temporal bounds. In the classrooms constructed through participants' accounts, relationships between students and between students and their teachers are shallow, the purposes of learning activities are vague or trivial and neither the teacher nor students exercises agency.

These accounts of the classroom are very similar to accounts of public education in the United States provided by several authors (Baez & Boyles, 2009; Gee, 2004; Lemke, 2007). These authors argue that public education is currently defined by the reductionism and instrumentality of Scientism as expressed through the hegemony of an alliance between government and business. These authors argue that applying the principles of Scientism to education has been the same as its application to business. It has resulted in the disempowerment and trivialization of teachers as educational practitioners, the trivialization of the work associated with schools, an attitude of instrumentality in which students and teachers are seen as mere cogs that can be manipulated to “improve” results, and in the destruction of structures that once provided opportunities for communities to be formed.

I will argue that the elements that suffuse the participant accounts of their experiences in the classroom, and the Discourses from which these accounts spring, may be a result of the educational context described by these authors (Baez & Boyles, 2009; Gee, 2004; Lemke, 2007) in their theoretical/philosophical works. I will further argue that the science classrooms constructed by study participants in their interviews are science classrooms where it is very unlikely for Science Discourse to occur.

Very briefly, Scientism is a philosophy that holds that science is not simply one of several valid ways of knowing the world and evaluating knowledge claims; instead, it is the only valid way to know the world and to evaluate knowledge claims (Habermas, 1971). In the Modern Age, it became the dominant epistemological stance in western societies (Outhwaite, 1994). American society hopes that Scientism will bring the same consistency and certainty to American education that it has brought to American business, particularly as expressed in the modern Capitalist Business Model (Baez & Boyles; Boyles, 2007).

*Scientism and the disempowerment and trivialization of practitioners.*

As applied to industry, Scientism is responsible for the modern factory and its methods of efficiency. When science, as part of a move to modernism, was applied to industry, the work that formerly took place in artisans' workshops and at the pace of the artisan was moved to a central location, and became the subject of scientific time/motion studies. Under this approach to production, the procedures that were formerly the province of the artisan became the subject of efficiency engineers. What formerly was the property of workers was "removed from the workers' heads and bodies and placed into the science of work, the rules of the workplace, and the knowledge of managers and bosses" (Gee, 2004b, p. 95).

As applied to modern education, in the form of the testing movement, particularly as expressed in NCLB and centralized control over curricula, the application of science has done to the role of teacher what it did to the role of the pre-modern artisan. The teacher's role and expertise in these matters has been replaced by the centralized educational expert that offers fixes for faulty methods of production in the form of out-of-the-box Best Practices (Baez & Boyles, 2009; Boyles, 2007; Gee, 2004; Lemke, 2007).

I contend that through the claims about Scientism applied to education provided by Baez & Boyles (2009), Boyles (2007), Gee (2004) and Lemke (2007) one may form a plausible explanation for what we hear in George Mitchell's Teacher Discourse. When the W.A.R. faculty mentor spoke of conditions within his classroom, he talked about how little agency he felt. He spoke of his inability to hold students to deadlines or to create an atmosphere in his classroom where students have the time to do activities that give them the opportunity to get their hands on things, try things out; to fail, reflect on their failures, modify their approaches and try something different. He spoke of how he wished for sufficient time for his students to learn through their experiences. He spoke of his wish that students experience and come to understand that there are many answers to a problem and not just "one way to do it." He spoke of the constraints that he felt he was under to cover the expansive curricula that he taught. He spoke of the stress that he felt because of the requirements of high-stakes tests that are part of No Child Left Behind and the emphasis that his students placed on grades. He characterized himself as someone who was, in many ways, powerless in his own classroom.

All of these things that he regretted not being able to offer his students are, in his view, unavailable because of impositions from outside his classroom. It is reasonable to assume that if these matters were left up to him, Mitchell would do things differently, but they are not left to him to decide. This classroom account must be placed against the extracurricular context of FRC, where, when these impositions were absent, the features that Mitchell counts as lacking in his classroom were available to students participating in FRC. Mitchell's account of the classroom is consistent with work by Baez & Boyles (2009), Boyles (2007), Gee (2004), Lemke (2007), Ritchie & Rigano (2002) Tobin & Mc Robbie (1996), who also find the classroom broken and deficient in some important ways.

*Scientism and the trivialization of the work associated with the classrooms.*

An additional feature of modern institutions that are dominated by Scientism is the trivialization of the work and products that come out of them (Baez & Boyles, 2009; Buber, 1958; Gee, 2004; Lemke, 2007). In modernized industry, little importance is placed on the product of the anonymous worker's labor beyond its ability to perform in the market by turning a profit. This stands in contrast to pre-modern times, when the artisan's work was an immediate end in and of itself, and was a means of establishing an identity within the community at large and within a community of artisans producing similar products. When we see that Mitchell's Teacher Discourse and the student team members' Student Discourse was turned outward and away from the classroom and toward matters centered in power and authority outside of the classroom we are seeing the cause of the trivialization of their classrooms' products.

As this contention applies to Student Discourse, I mean that in the language that the student members of the robotics team used as they spoke of the science classroom, they did not speak of things over which they believed they exercised some control, such as relationships, activities, experiences or accomplishments that gave them personal satisfaction. Instead, they spoke of shallow relationships with classmates and their teachers, of relationships that were forced on them by factors beyond their control. They spoke of activities that seem to have frustratingly vague goals. They spoke of activities that seemed to require little thought and to have little purpose beyond the performance of a procedure that resulted in an expected outcome. Regarding the level of inquiry that was necessary to engage in science class activities, some students indicated that they saw the activities as trivial or as a sort of sham.

Their language indicated that they felt little ownership or connection with the activities in their science classrooms. Their language gave no indication of student agency in selecting the activities, structuring the activities or having control over their outcomes. Students spoke of being compelled to attend school, and being compelled by graduation and post-secondary institutional requirements to take the class. Their concerns centered on getting the work done and earning a good grade. All of these things showed that the students really did not identify with the activities and products of their classroom.

For them, these activities had no immediate value; in that regard, they were trivial. The only value that they saw in their efforts in the classroom was their ability to "turn a profit" at a future time in the form of parental approval, and entry to their school of choice. These student accounts of the science classroom showed that for them all loci of valuation lie outside of their control, and that for them education had become nothing more than "mere procedural consumeristic expectations" (Boyles, 2007). Risking redundancy, I must comment that this orientation is very different from that associated with student accounts of FRC activities, which included expressions of great satisfaction and personal identification with the products of their efforts and close relationships with team mates.

This student view is similar to their faculty mentor's view of activities in the science classroom. His language showed that he, too, saw little immediate value in many science classroom activities. Instead, he saw the valuation of his and his students' efforts resting with the assessors of benchmark test results, EOCT scores, GHSGT scores, etc.

*Scientism and the reduction of human beings to instruments of production.*

I have already noted the lack of agency that is portrayed in both student members' and the faculty mentor's accounts of the science classroom and its activities. It might be claimed that these accounts are not authentic; that in fact, in particular teachers, exercise control over their classrooms. Here, again risking redundancy, I call forth a comparison between the accounts of agency pertaining to FRC and the science classroom. By comparison, any student or teacher agency that was part of the accounts of the science classroom were trivial when compared to that exercised by either group in robotics.

Even though students and the teacher who participated in the study exercised little agency in determining how learning would occur in the classroom, things still happened in the science classroom. If the way that learning unfolds in the science classroom is not the result of teacher or student agency, on whose authority are the classroom's activities being planned and conducted? I argue that here, as with the modern factory, these decisions are external to the factory floor. These decisions are made by experts who monitor production and maximize it by instituting standardized production practices. "Best Practices" is the term used in education for methods that try to make standard and certain that which should never be standard, and in the sense that scientific cause and effect appears to be certain can never do so.

Scientism as it is applied to the science classroom has reduced students and teachers to variables that can be manipulated to insure standard outcomes in the form of the politically valuable commodities that support educational reform and claims of its success (Baez & Boyles 2009; Gee, 2004; Newton et al., 1999).

*Scientism and the destruction of community.*

One of the key elements that was highlighted in participant accounts of W.A.R.' s 2008 season were the types of relationships that participants experienced. Much has been made of the contextual factors that contributed to the relationships' quality and made them possible. It has also been noted that these sorts of relationships were part of neither the faculty mentor's account of his classroom nor of student teammate accounts of their science classrooms. One result of applying Scientism to industry was the destruction of communities that existed in the pre-modern era (Buber, 1958; Friedaman, 2002; Gee, 2004). The character of these institutions was the freedom of association, the voluntary nature that surrounded their formation and membership. These sorts of communities certainly had elements of instrumentality in their purposes. According to Buber, this instrumentality was “the necessary and ordered realm of the world of It” (Friedman), but they left open the possibility of non-instrumental interaction between their members that might result in what Buber called dialogue (1970). Buber’s (1958) take on the effect of Scientism on institutions is as follows:

> [In the past] wherever historical destiny had brought a group of men together in a common fold, there was room for the growth of a genuine community. . . . A living togetherness, constantly renewing itself, was already there, and all that needed strengthening was the immediacy of relationships. In the happiest instances common affairs were deliberated and decided not through representatives but in gatherings in the market-place; and the unity that was felt in public permeated all personal contacts. . . . All this, I may be told, has gone irrevocably and forever. . . . The pressure of numbers and the forms of organization have destroyed any real togetherness. Work forges other personal links than does leisure, sport again others than politics, the day is cleanly divided and the soul too. These links are material ones; though we follow our common interests and tendencies together, we have no use for "immediacy." The collectivity is not a warm, friendly gathering but a great link-up of economic and political forces inimical to the play of romantic fancies, only understand-able in terms of quantity, expressing itself in actions and effects--a thing which the individual has to belong to with no intimacies of any kind but all the time conscious of his energetic contribution. Any "unions" that resist the inevitable trend of events must disappear. (pp. 135-136).

When we hear student participants’ “our,” “we,” and “us” become the indefinite “you” and the faculty mentor bemoaning the sorts of relationships that he has with his students, we are hearing through their respective Teacher and Student Discourses the effects of Scientism on their relationships within their educational institutions. We are hearing them decry the lack of immediacy that is part of their classroom relationships. We are hearing them decry the “great link-up of economic and political forces inimical to the play of romantic fancies, only understandable in terms of quantity, expressing itself in actions and effects” (Buber, 1958, p. 136). We are hearing the discursive deficiencies and brokenness of the science classroom. As Lemke (2007) comments,

> Why do we imagine that in a society as complex as ours you can learn what is important or valued in our society by sitting in an empty classroom, by spending all your days in one building? We bring in books and pictures, slides and films, televisions and the Web. But those are poor substitutes for observing and participating in at least some of the millions of real activities in real places in our society. No other buildings are as empty as schools, except perhaps for prisons. (p. 3)

For the social constructivist, this inability to foster community is the aspect of Scientism’s influence on the science classroom that renders it finally discursively deficient and broken. If individuals cannot be present to one another, there is no dialogue. If there is no dialogue, there can be no community of learners. But for an education research community and a policy elite that are dominated by the principle of Scientism, much of what constitutes the dialogue of science classroom inquiry and its concomitant Science Discourse are “ . . . ‘problems’ or ‘challenges’ or noise’ to be corrected and controlled but only by the scientists themselves” (Baez & Boyles, 2009. p. 67).

On the basis of the study’s data and my interpretation of it, the principal reason that inquiry such as that advocated and described in AAAS (1993,1990), NRC (2000, 1996) and experienced by W.A.R. student team members during the 2008 FRC is absent in American public school classrooms is the basic discursive nature of the public school science classrooms that are constructed as parts of the student team members’ and their faculty mentor’s accounts. The discursive nature of these classrooms is a direct reflection of the interests of the dominant voices that speak these classrooms into being and articulate their intentions for them.

Finally, I am suggesting, as do Duschl & Osborne (2002), Jimenez-Aleixandre et al. (2000) and Watson et al. (2004), that under the broad societal acceptance of Scientism, the cultural expectations for schooling held by students, their parents and the society at large may be so fixed that the traditional classroom setting may be the biggest obstacle to successful scientific inquiry. I am suggesting that in at least the case of W.A.R. for both students and teachers, the classroom has become such a sterile place that activities associated with it may have little chance of bearing the sort of fruit that can be cultivated in an extra-classroom or extracurricular setting.

*Conclusion Four*

I have made the argument that the FIRST Robotics Challenge provided the W.A.R. team with a context that interacts reflexively to reproduce many elements of a community of professional scientists or engineers. It might be argued that this authenticity extends to and reproduces many of the inequities and the lack of diversity that are found in the real world of science and engineering.

However, placing the explanation for the types and levels of participation observed among the female members of W.A.R. in, this argument ignores the fact that all of the W.A.R. team members came to FRC as male or female participants in other Discourses (Gee, 2005, 2001). These Discourses set limits for proper male and female participation in those Discourses. For the female members of W.A.R., these might include the Girl-in-High-School or the Active-Female-Member-of-a-Conservative-Protestant-Denomination Discourses. For the male members of the team, the Discourses that they brought with them to W.A.R. and FRC might be equally responsible for proscribing levels and types of female participation with the robotics team. The identities and the values associated with these other Discourses might be as responsible as any other factor for determining how female members of W.A.R. participated in FRC.

## Implications for Science Education

My study has provided some insights into how language and context interact to permit students and teachers to enact Discourses during the student-centered science learning activities of FRC. The study has concluded that student and mentor Discourses associated with FRC are the result of elements within the structure of FRC that are, in many ways, very similar to communities of practicing scientists.

From the study data, I have also concluded that the science classroom is discursively deficient and broken. Where formerly, the classroom was spoken into existence by a broad alliance of interests (Newton et al., 1999), now it is dominated by the strong voice of Scientism through an alliance of government with business (Baez & Boyles; Gee, 2004; Lemke, 2007; Newton, et al. 1999). Where research shows that after many years' attempts to institute science pedagogy based on student-centered inquiry, science classrooms in the United States are still dominated by teacher-centered lessons, and those activities that do involve students hands-on fall short of inquiry. I contend that the discursive nature of the science classroom is a chief cause of the problem. I contend that until this aspect of the science classroom is changed, the realization of the sort of science inquiry learning within the confines of science classrooms and their curricula will be unlikely.

Having noted this, the literature does include some examples of successful science learning through inquiry. Sometimes this learning takes place in the context of extended projects. Frequently, these successes occur outside of the school classroom in extracurricular projects (Almeida, Bombaugh, & Mal, 2006; Bernard, 2003; Morris, 2004). As noted in the second chapter of this study, the majority of examples that I was able to find for successful inquiry, particularly extended inquiry that was centered in classrooms, frequently took place in private schools (Roth, 1993; Roth & Bowen 1995; Roychoudhury & Roth 1996; Warren & Rosebery, 1996; Rosebery et al., 1992). When successful extended inquiry occurred in public school classrooms, these are frequently not located in the United States (Mercer, et al., 1999; Roth, 1993; Roth & Bowen 1995; Roychoudhury & Roth, 1996; Watson et al., 2004).

*Teachers Must Overcome the Flaws Inherent in the Classroom*

The study findings imply that in the case of the W.A.R. team members and their faculty mentor, the public school classroom was the problem. The study findings and the literature seem to indicate that, for students, the purpose of the classroom is doing school (Duschl &Osborne, 2002; Jimenez-Aleixandre et al., 2000; Lemke, 1990; Watson et al., 2004), not doing inquiry. The study findings and science education research also indicate that, for science teachers, the classroom has become a place for doing accountability (Baez & Boyles, 2009; Boyles, 2007; Newton et al., 1999; Tobin & McRobbie, 1996). The classroom is the problem.

Lemke (2007) suggests that the traditional classroom setting may be so flawed that it and traditional schools should be abandoned in favor of alternative sites and modes of education. While other critics of current educational policy and practice are not quite so condemnatory as Lemke, Boyles (2007) suggests that the policies of NCLB are absurdly flawed and abusive and have made genuine learning very difficult in today's public classrooms.

So, if all public school science students lack access to inquiry science learning through programs like FIRST or through other means, how can this sort of experience be made available to them? Unsuited as it is to science inquiry, if students are to have access to these opportunities, they must be made available in the science classroom. How will this be possible? If this is possible, how will the Inquiry Science Classroom look?

The Inquiry Science Classroom will be a place transformed by students and teachers that

- is defined by science learning activities with elements that promote Science Discourse and by taking into account student perceptions of activities
- fosters a classroom community by
    - providing sufficient time for the activity.
    - providing social structures that foster community.
    - providing challenging science-learning activities that require the efforts and skills of the class.
- is not limited by its walls because
    - it builds a community beyond its walls with learners with similar interests
    - it utilizes the resources of experts from the school's community
- it empowers students by making them co-owners of the class and its activities.
- it empowers students and teachers choose challenging leaning activities that;
    - offer alternatives to scripted learning activities
    - offer alternatives to superficial and meaningless assessments
- it accommodates a variety of marginalized science learners through science-learning activities that require a broad range of skills
- it is "messy" like science

*Suitable Science Inquiry Activities Essential to Science Discourse*

I am suggesting that it is the students' perceptions that count here. They count above those of teachers, administrators and policy-makers. An implication of this study is that the type of activity chosen for inquiry learning is very important if Science Discourse is to be enacted during science learning activities. Students and teachers must choose activities in which students can clearly perceive and understand the need for science inquiry. Everyone involved in the science classroom must understand that inquiry is the goal of science learning activities.

This requires that for inquiry set in the classroom, the science classroom must be purged of its typical activity patterns, and that the activities and customs of science must replace them if Science Discourse is to be part of science learning (Jimenez-Aleixandre et al., 2000; Lemke, 1990) and climate (Lemke, 2007; Newton et al., 1999; Ritchie & Rigano, 2002; Tobin & McRobbie, 1996).

Research (Jimenez-Aleixandre, 2000; Lemke, 1990; Roth & Bowen, 1995; Watson et al., 2004) shows that the activities that the students do are cookbook exercises that are limited to one or two class periods. The activities seem to be vaguely related to the topics of the class, but these topics seem to be only loosely relevant to student lives. As with the student participants' experience of robotics, the science classroom must provide the clear evidence that an inquiry science class is a different learning context from the typical science class, with different customs, different patterns of activity and different expectations for students and teachers alike.

Apparently, W.A.R.'s student team members' perceptions of FRC were sufficiently different from traditional science learning activities that students saw them as activity that required, and merited, inquiry. Projects like FRC are very different from traditional science learning activities. They are different because the order of things is turned on its head.

In the context of an open inquiry science-learning context, students have real power because their ideas, to a large extent, determine how the activity unfolds. Unlike lab exercises that are designed to confirm some relationship among variables or a connection between a cause and an effect, these projects' outcomes are never assured, and hinge on the creativity and, to some extent, the persistence of the group. At completion, projects such as the FRC have concrete and easily assessed results. There is the robot and the robot's record in the competition. All of these factors separate the W.A.R.'s FRC experience from their accounts of their experiences in their science classes. This arrangement is very different from what students generally experience in their science classrooms.

In keeping with these findings, if Science Discourse is to be part of science inquiry learning, the type of activity chosen by teachers and students, and the circumstances surrounding its selection, are crucial (Duschl & Osborne, 2002; Jimenez-Aleixandre, 2000; Watson et al., 2004).

*Creating a Learning Community is Critical to Science Discourse*

The formation of a community of learners greatly contributed to the W.A.R. student member's enactment of Science Discourse. The elements that the current study identifies as important to the formation of community are time, social structures and challenging science-learning experiences. The study findings show that the W.A.R. community did not form simply because somebody told the student team members, “Hey! Ya’ll will work together on this problem.” Rather, the community formed over time as a result of shared experiences to which students often referred when they spoke of themselves in terms of a cooperating group. Therefore, in planning inquiry activities, students and teachers must schedule sufficient class time for community to develop. In the case of W.A.R., the time that the student team members and mentors spent together gave the team sufficient opportunity to develop a shared history that frequently was the focus of the language that was part of the team’s community identity.

In addition to sufficient time, when students and teachers select and plan science-learning activities, those activities must be structured to provide a social framework around which community can form.

The sharing of an evening meal was part of most evening work sessions. This meal was dished up by a couple of teammates’ parents or the spouse of one of the mentors and served as an important event around which a sense of community developed. There is absolutely no reason why student planning and work on classroom science-learning activities cannot include food sharing and other basic aspects of social activity known to foster a sense of community. Set against the science classroom experiences of W.A.R’s student team members, this communal act, the sharing of food, lifted their learning experience from the classroom restricted by the ringing of bells and circumscribed by the instrumental nature of its context, to an experience that is at the heart of community.

The W.A.R. student team members’ accounts of their science classrooms described science classrooms that were devoid of any sense of community and that were lacking the basic elements around which communities might be formed. This study also asserts that these accounts are a reflection of a public education system dominated by a Scientistic worldview born of a union of government with business interests. A result of this domination is the separation of teachers and their students from a community of others with similar interests.

Therfore, when students and teachers select and plan inquiry-learning activities for their classroom, they must incorporate an aspect of show-and-tell that takes the student beyond the bounds of classroom community into a broader community of learners with similar interests. If an aspect of inquiry and, by extension, Science Discourse, is displaying and explaining one's work to a community of scientists, then real inquiry science learning would also include a genuine element of this sort of performance.

For W.A.R., this meant becoming a part of a very broad community of co-investigators that met online to discuss problems and share ideas, and met head-to-head for a competition. The potential for this sort of networking and competition is imminently possible in many schools, is within the abilities of many students, and can, with some effort, become a way that students share their work with a community outside their classroom. To do this, classes at different schools that are involved in similar activities might network with one another to share ideas and successful approaches to solving problems and make online presentations to one another, highlighting project results.

In choosing activities for inquiry science learning there are a number of considerations. It is not enough for students and teachers to choose activities that will foster a learning community. Students and teachers should select activities that are at-the-limit-of-to-slightly-beyond the experiences and capabilities of the students. Studies show that if students perceive that an activity is simply more of the same classroom activity pattern, they will treat it as such (Duschl & Osborne, 2002; Jimenez-Aleixandre, 2000; Watson et al., 2004). If an activity does not stretch students' abilities, knowledge and skills, there is no need for students to combine their knowledge and abilities with their classmates'. Without this aspect, each student will simply do the activity alone (Duschl & Osborne, 2002; Jimenez-Aleixandre, 2000; Watson et al., 2004).

Projects that are at the limit of or slightly beyond the experiences and capabilities of students are said to lie at the students' Zone of Proximal Development (ZPD). This is a term employed by Vygotsky (1978) to describe the level of development at which a learner requires assistance from an adult, such as the mentors of the W.A.R. student teammates. Of course, within any group of learners there are many ZPDs, but this, too, can be a means of forming community as classmates who are more capable or who have different experiences serve as student mentors to their classmates (Roth, 1993; Roth & Bowen, 1995; Wertsch & Toma, 1991).

There are several features of the FIRST robotics program that may suggest ways to address some of the difficulties encountered while to trying to introduce authentic inquiry to the public school classroom. All of these center on the basic differences between what typically goes on in the science classroom and the things that were done, and the way those things were done, in the case of the W.A.R. Robotics team during the 2008 season.

*Breaking Down the Walls of the Science Classroom.*

Several aspects of W.A.R.'s experiences in FRC were characterized by elements that are not regular parts of the science classrooms that they described, or the classroom accounts that are part of science education literature. In general, these elements are not part of science classrooms because classroom walls often limit science classrooms. If inquiry science learning is to occur in public school classrooms, students and teachers must avail themselves of their communities' assets that lie beyond their classrooms . This means that students and teachers will have to break down the classroom walls.

*A modest proposal.*

Within a school and among its classes, competing communities can be formed that will perform various inquiry activities and test the products of students' inquiry efforts. For example, as part of an interdisciplinary geography, earth science and math project, students might form teams and challenge one another to a multi-disciplinary scavenger hunt. Teams could be formed from classes meeting during the same hour, and lay down a challenge to teams comprised of students meeting during other hours.

In preparation for the challenge, earth science students would locate and identify rocks and minerals lying within the bounds agreed to among the teachers of the classes participating in the scavenger hunt. A challenging team would devise clues for the opposing team to use in finding the target rocks and minerals. These clues might employ student-produced scaled contour maps that comprise part of the math/geography component of the activity. An math/geography component could be added to the scavenger hunt by having the students use the maps, compasses and written clues to locate and travel to locations to collect tokens that would earn points in the scavenger hunt.

Classes composing one team would pass their scavenger hunt along to the teachers of classes meeting at another hour. After the scavenger hunt maps, clues and so forth were exchanged, the hunts would be conducted during the hour that each team's classes meet. Scores could be tallied and an awards/pizza party could be held to announce the results and recognize outstanding performances. This sort of activity would bring students' inquiry efforts beyond the bounds of their classrooms into a broader association with other students involved in similar inquiry. It would also give student groups an opportunity to show their efforts and examine the efforts of others.

The proposal that I make is tailored to an integrated multi-disciplinary earth science/geography/math project, but it is easily adaptable to other science areas, such as biology. Substitute leaves/fruits of plants for rock and mineral samples, and the science component of the project changes, but the other elements of the project are retained.

Watson et al. (2004) suggest that this sort of exercise is necessary for students involved in inquiry activities, and without it, students resist or simply do not see the need of discussing or explaining themselves before classmates and a teacher who, already know full well what their activity has been or what result their work has achieved.

Lemke (2007) writes at length about the public schools' failure to utilize the resources of the community that lies beyond their walls. For W.A.R., these resources were an essential aspect of their experience in FRC. The role of the mentor heavily influenced the quality of W.A.R.'s experience. Science education literature notes that many teachers simply do not have the knowledge to lead a class through such an experience (Kelly et al., 2000; Lemke, 2007; Roth, 1995; Roth & Bowen, 1995). So, if projects such as that presented in FRC are to become a part of classroom inquiry science learning, their level of complexity may require that classroom science teachers and students go beyond their classroom's and their school's walls to seek the help of experts from the community in which the school is located. These experts can serve as guides who can assist the teacher and the students in acquiring elements of a new Discourse that can be a part of these science-learning experiences.

*Alternatives to scripted superficial learning.*

Currently the classroom is dominated by highly scripted and superficial learning that reflects its domination by a Scientistic view of education. Another implication of the study's findings is that as an antidote to this view and its result, teachers and students should choose science inquiry activities that offer opportunities for students to apply "book knowledge" to real-world situations. A strong theme in the language of the W.A.R. student team members was the scripted inauthentic nature of the science learning activities that they encountered in their science classrooms. This was one aspect of the science classroom context that contributed to its emptiness.

*Alternatives to superficial and meaningless assessments.*

Another feature of our public school science classrooms, particularly as represented by GHSGT Science Test, and EOCTs in Biology and Physical Science, is its domination by superficial and meaningless assessments of science learning. For some students, science inquiry activities that offer opportunities for students to apply "book knowledge" to real-world situations provide students and teachers with a meaningful alternative way to judge progress and a means of alternate assessment that can be added to those more traditional assessments. Therefore, students and teachers should consider products of applied science projects as a means of alternate assessment that can be added to or replace more traditional forms of assessment.

For W.A.R. the robot and its performance provided a means of assessment that for student team member Patrick Pitcher was more meaningful than the assessments that he experienced in his science classes. For Patrick, the goals of the science learning assessments were unclear and only vaguely connected to his lab experiences. He talked about how the progress and the success of the robot provided a sort of assessment that was concrete, and, for him, preferable to the sorts of assessments he experienced in his science classes.

This the results of this study show that the practical, real-world aspect of a project built around a technological problem made FRC such a compelling experience for the students learning science through FRC. As the study data and its analysis showed, basic science concepts were taught and applied in W.A.R.'s experience of FRC. The design and building of the robot required the application of basic physics principles. These aspects of basic science came into play again at the end of the competition, when assessments were made of the robot's performance. These assessments reversed the design process and asked whether the assumptions that were made about the root science that underlay the design and engineering decisions were correct, and, if not, where the errors in those assumptions were made. W.A.R.'s example shows that the integration of teaching science principles with technology is an effective means for teaching the practices, values and attitudes of scientists.

The goals of AAAS (1993, 1990) and NRC (2000, 1996) deal with inquiry activities that teach science principles, practices and values through the sorts of activities that are part of the practice of pure science. These policy documents do not address the possibility of teaching science through technologically based projects. These important policy documents do, however, address the interconnectedness of pure science and technology. They even address the need for scientists, at times, to design and build new technologies in order to investigate a scientific question. NRC (1996) goes to considerable length to explain that technology has more impact on human lives than science because the purpose of technology is to solve humanity's problems.

*The Problem of Science Inquiry for Minority and Marginalized Students*

The literature tells us that for students who come from families of particular social or ethnic backgrounds, science inquiry learning is very difficult (Brown, 2006, 2004; Lemke, 2007, 2001, 1990; Roseberry et al., 1992; Warren et al., 2006). Including projects with applied science features, such as FRC's, in the regular science classroom may be a route to science inquiry for minority and marginalized students. Therefore, in choosing science-learning activities, students and teachers should consider, for these groups especially, the opportunity for successful inquiry science learning presented by applied science activities.

W.A.R.'s student team members reflected the demographics of the schools from which its members were drawn. Its example, therefore, does not directly address the science learning of minority students. However, W.A.R.'s experience of FRC provided an attractive avenue for "non-science types" to participate in an extended inquiry project. Pavlova Kinsky, a W.A.R. student team member, told how the support that she got from more knowledgeable teammates helped her feel comfortable with a field that she had never considered before.

Some educational research indicates that students have difficulty envisioning themselves as scientists (Brown, 2006; Watson et al., 2004). This is particularly true for students who are from backgrounds where the language of science is yet one more unfamiliar aspect of an already unfamiliar language, or where the thought of becoming a scientist seems unachievable or even, in some cases, undesirable (Gallas et al., 1996; Gutierrez, 1999; Lee, 2001; Moje et al., 2001).

For some of these students, the building of a robot may be a more immediate and practical activity that is free of some of the linguistic challenges associated with learning vocabulary, technical and academic writing  and disembodied theory of their science class experiences. Further, the activity of building a robot with a group of other students may place the marginalized student on a more nearly even footing with peers, while providing a means of joining a community that might help the student integrate into the school's life and, if needed, provide an opportunity to improve conversational linguistic skills.

Another aspect of FRC that makes it an even broader avenue for involving a category of marginalized science learner, the self-described "non-science types," in inquiry is the fact that FRC involves much more than designing and building a robot. In the case of W.A.R., FRC made room for a "gearhead" who was good with mechanical problems, but cared nothing for the abstractions of chemistry. It made room for the computer 'geek" wto enjoyed both gaming and game design, but began to fidget when confronted with a taxonomy scheme in biology. FRC made room for the special education student who was adept with computer-assisted design programs such as AutoCAD. FRC made room for students who were artistically talented, but never imagined that they could be a part of a science and engineering project.

Projects such as FRC place these diverse individuals on an even footing with one another and throw them together to work toward a common goal. Through their association with the project, these diverse individuals begin to think about themselves and others in different ways. This sort of experience was advocated by Dewey (1916) because these qualities had the ability to instill the values and attitudes that he found essential to democracy. Through this association, some who may never have considered it start to see the possibility that the people who do engineering and science in real life are people like themselves. Gee (2004) sees this implication, too. He writes,

> It is often enough that they have sensed new powers in themselves. They will, possibly for a lifetime, be able to empathize with, affiliate with, learn more about, and even critique science as a valued, but vulnerable, human enterprise. (p. 114)

Veteran teachers will need the support of teachers who already teach in Science Inquiry Classrooms. Through this support and through in-service-training they can receive a background in the philosophy, theory and techniques that underlie inquiry science teaching. If science inquiry takes place in the classroom and Science Discourse is an element of that inquiry, teachers must be prepared for the classroom that was once inimical to Science Discourse to look and feel very different from the classroom of scripted cookbook labs.

Science is contentious and messy (Hammer, 1995; Salyer, 2000; Scott, 1998; Scott et al., 2006). Teachers attempting to transform their old classrooms into Science Inquiry Classrooms must be prepared for the unease that comes with unfamiliar roles that place them in different relationships with students and their own work and their students' work.

Research shows that teachers are resistant to teaching science through inquiry (Spector, Burket & Leard, 2007), so teacher training must prepare teachers for this type of teaching and acquaint them with the advantages and benefits that inquiry science teaching can have for them and their students. First, teachers will need to acquire an understanding of and appreciation for the philosophy and theory in which inquiry learning is grounded. Some who have looked on science education as learning vocabulary and solving pencil and paper problems will need to understand the learning goals of the Inquiry Science Classroom and the value that this sort of science learning can have for the student and society. Planning and teaching activities that integrate knowledge from a variety of science disciplines requires that teachers have both a broad and a deep understanding of science content. Teachers who are accustomed to an always quiet and orderly classroom will need to experience an integrated multidisciplinary approach to teaching science topics, and learn the classroom management techniques that keep a learning carnival from descending into unproductive chaos.

In these new roles students and teachers must engage in unfamiliar activities, use unfamiliar resources, use familiar resources in different ways and adopt different values. In short, teachers and students doing real inquiry science learning like that examined in this study must enact Discourses that are probably new to them.

When a teacher shifts from the traditional role to become a facilitator and knowledgeable co-investigator, and students take an active hand in planning and conducting learning experiences, there is a shift in power (Hellerman et al., 2001; Kelly et al., 2000; Ritchie & Rigano, 2002; Roychoudhury & Wolf, 1996; Rodriguez & Thompson, 2001; Salyer, 2000; van Zee, 2000). Roles change in other ways, too.

So for those of us who teach science in public schools, where there is little space for this sort of teaching, some of these projects will never reach their intended goals, and for the near term extracurricular activities like science fair projects, FRC, FIRST

LegoLeague, Science Olympiad and similar programs are likely remain important avenues for extended science inquiry learning.

## Implications for Educational Research

The current study has provided some interesting insights into how language and context interact to permit students and teachers to enact Discourses during the student-centered science learning activities of the FRC. A key insight is the way that the student participants and their faculty mentor use very similar language in very similar ways in speaking of the traditional science classroom and FRC.

On the basis of these accounts and these characterizations of the science classroom and the language used to construct them, it seems that the students and the teacher are describing the same places, toward which they have very similar orientations and attitudes. There are authors who give glimpses of similar classrooms peopled by similar teachers and students (Gee, 2004; Lemke, 2007, 1990). There are even authors (Baez & Boyles, 2009; Boyles, 2007; Gee, 2004; Newton et al., 1999; Ritchie & Rigano, 2002; Tobin & McRobbie, 1996) who offer explanations for how these classrooms might have come to be.

Some of the implications for future research come directly out of the weakness of this study. In this study, the claims that are made about the nature of the science classrooms are constructed from participant responses to questions about science classrooms rather than from language collected in the context of learning activities in a science classroom. This is the piece that is missing from this study.

In light of this deficit, several questions remain unanswered. First, science students and the science teacher gave an account of a classroom that was dominated by strong voices from outside the classroom. A study of language and the learning context in a science classroom would provide an opportunity to determine whether this study's assertions about the state of the science class are evident in an actual science classroom. It would provide an opportunity to determine if and why the classroom under study is actually broken for the students and their teacher. Such a study would provide an opportunity, if one exists, to hear and listen to those strong voices in the actual context of the science classroom, and understand how they contribute to its learning context. If language and context interact with one another to build Discourses, what Discourses are within the control of students and teachers in such a classroom?

There are several authors, Watson et al. (2004), Tobin et al. (1996) and Tobin & McRobbie (1996), who have scratched the surface of this line of research. In Watson et al. (2004) the authors tried to account for why inquiry was so hard to institute in science classrooms. The authors borrowed the idea of Socio-cultural Influences (SCI) from Bloome (1989) to explain what the authors referred to as procedural displays. According to Watson and his co-authors, procedural displays are responses to a learning activity that are motivated by the culture of the class rather than what is called for by the design of the activity. They see these responses arising from a group understanding of what it means to do science learning. Watson et al. (2004) feel that SCIs may arise from two sources, from inside the classroom or from outside of it. While I am not certain that the inside and outside distinctions are valid, given the institutional genesis that all public schools have, I agree with the authors that SCIs define the ways that schools can operate by setting the standards for what learning and how that learning is to take place in their classrooms.

The study that I would propose could extend the findings of the current studies and those mentioned in the literature above. This study would be based on the hypothesis that science classrooms utilizing more open inquiry types of science learning would be significantly different discursive environments from those where more teacher-centered approaches to science learning predominate. Further, the study that I would propose assumes that the differences in the context of these environments would be, at least in part, a product of sociocultural influences (Clegg, 1989; Newton et al., 1999; Ritchie & Rigano, 2002; Tobin & McRobbie, 1996), and, by extension, the language used in those classrooms would provide evidence of those influences.

I would propose that the study apply CDA to language recorded in the context of science-learning activities from two classrooms. I would choose CDA as a methodology/method because my suspicion, based on this study and work by Clegg (1989) Newton et al. (1999), Ritchie & Rigano (2002) and Tobin & McRobbie (1996), is that these differences in these learning contexts will be tied to issues of power related to the classrooms' learning contexts. Semi-structured interviews could be used to examine the themes that arose from the CDA. The discourse analysis might uncover how the context of the learning environments is influenced by factors internal to and external to the classroom. The classrooms would be selected on the basis of the willingness of the teachers to participate in the study and the predominant role of one of these approaches to science teaching in that particular classroom.

A study of language in the context of a science classroom would provide an extension of the present study and those above. It might establish if there are indeed strong voices that dominate the Discourse of the science classroom. It might clarify if and how these voices (if they are present) operate to constrain the possibilities for learning in the science classroom.

Finally, that the FIRST Robotics Challenge reproduced elements of the culture of practicing scientists and engineers for the members of the W.A.R. team is, in general, a desirable result. However, the fact that it also reproduced the same skewed level of participation for males and females that are found among professional scientists and engineers is troubling in a society that claims to value diversity and equality of opportunity.

When these numbers are joined with the personal accounts of female team members' status as outsiders with respect to certain team activity, there is cause for real concern. Several authors of recent studies have noted that female students are frequently relegated to the margins of science and mathematics in the science classroom (Kahveci, Southerland & Gilmer, 2008; Tan & Barton, 2008). These authors also report that many of the same elements that are a part of the W. A. R. team's account of their participation in the FIRST Robotics Challenge have been successfully employed in bringing female students from their status as science outsiders to a new status as science insiders. In light of these study's claims, it would be useful to know whether the females of other robotics teams see themselves as outsiders with respect to certain team activities.

I would propose that a future line of research investigate boys' and girls' attitudes toward participating in FRC or in a project similar to FRC, and how these attitudes might serve as a route to or barriers against participating in the program. The research design might initially use a carefully designed questionnaire that would provide insight into these attitudes. The sample for the study should be drawn from girls and boys from a school with an FRC program, and include both boys and girls who are participants or non-participants in the schools FRC team. After assessing the questionnaires, students might be interviewed to clarify their attitudes and to learn what factors underlie those attitudes.

An extension of this study might do a similar study of girls that participate in one of the few girl FRC teams that are active, with some Girl Scout Troops and students from girls' schools. This population might also provide an opportunity and interesting route to study the factors that contributed to the different status that the girls of W.A.R. reported in regard to the roles that they played on the team. On W.A.R., girls took a very limited role in the technical hands-on aspects of the program, such as building the robot, programming the computer interfaces for the robot control systems and driving the robot. The most jarring aspect of the girls' accounts of their roles were their statements about being "invited" to participate in the building of the robot.

An all-girl team might provide a means for investigating the possible cultural attitudes that might serve as barriers to unforced full and equal participation that could be present in a mixed gender team, but lacking on an all girl FRC team.

The findings of the current study are that, given the goals of AAAS (1990, 1993) and NRC (1996, 2000), the W.A.R. team members and their mentors were involved in a successful student-centered science learning experience. The present study also identified several elements inherent in FRC that seemed to be responsible for this success. The current study also asserts that for the W.A.R. student team members and their faculty mentor, the science classroom is a discursively deficient and broken place that is unsuited to the sort of activities that were responsible for the Science Discourse that was a part of their FRC experiences.

In the Implications for Science Education section of this study, I made suggestions for transforming the classroom into a setting that would be more amenable to inquiry science learning and the Discourse that accompanies it. However, in light of the findings from education research and this study, a line of research should be pursued that might establish what is actually entailed in making the transition from a teacher-centered traditional science classroom to a classroom focusing on successful open inquiry science learning. The study might reveal what would be entailed in this process, what would the process would look like for teachers in classrooms under the demands of high stakes testing and highly structured centrally controlled curricula.

Rodrigues and Thompson (2001) note that the context of learning is more than just the physical setting in which learning takes place and the subjects that are being addressed. They note that context is a reflection of these and the hierarchical power that exists in traditional classrooms. They note that this power is imposed through language. They also note that trying to modify context through "simplistic prescriptions of teaching and learning in the use of thematic material as a means of teaching and learning in context demonstrates a failure to understand that teaching and learning exists in a linguistic framework" (Rodriguez & Thompson 2001, p. 939).

I would propose an action research study design for this study. This study asserts that the state of the science classroom is a reflection of the hegemony of the current marriage of business to government. Action research is an appropriate approach to this subject because action research concerns itself with issues of power and repression. Its goal is exposing the sources of repression, helping the oppressed to understand their state and helping to bring about the amelioration of the circumstances responsible for the state of the oppressed.

For this research to be conducted, a teacher who wished to make the transition from a traditional student-centered science classroom to a classroom focused on open inquiry would need to be found. In addition this study would require that both the on-site and the central school administrations agree to such a study. Since most school systems are recipients of federal and state education funds, and these entities are complicit in the hegemony that this study has identified as the agent responsible for the current state of public education in the United States, it seems unlikely that this research could ever be pursued. However, with these obstacles in mind, I note that Tobin et al. (1997) recounts a very similar study that was conducted in a public high school in Australia.

Should a study site be located, this study would require that the teacher, the researcher and the school administration agree to a long-term commitment to work together to identify their concerns about instituting inquiry activities in the science classroom and to agree to address them. Once these barriers and concerns were identified, the teacher and the researcher could work together to identify the factors that block the teacher's ability to have an Inquiry Science Classroom. For example, these might be concerns that she and the administration have about the ability of inquiry learning to prepare their students for high-stakes tests. If this were found to be the case, the researcher would work with the teacher and the students to plan activities that would assure that the students would be prepared for the standardized tests in the course of their inquiry activities. The teacher and students could work with the researcher to put these inquiry activities in place, and carry them out while making sure that both the inquiry goals and the test preparation goals were attained.

At the end of the year, after the dust settles and test scores have been reported, the researcher, the teacher, the students and the school administration could meet to discuss and reflect the impact that the action research had on all of the dimensions of the students' experience over the course of the school year. This discussion and reflection would need to address the concerns and goals of all of the stakeholders in the action research project. This discursive and reflective process would undoubtedly need to address standardized test scores, but should also address student attainments in the areas of problem-solving through inquiry, and the habits of science, along with the affective issues connected with the classroom environment. With hard work and application such research might bring successes that result in a wholesale change in policy about science teaching within a school and within a school system.

## Study Limitations

As originally conceived, this study was intended to examine the differences in Discourses that are implied by the different linguistic demands of teacher-centered science and student-centered science pedagogies. Because of changes that were required in the study design, this study was never conducted, and many questions that might have been answered or at least clarified by such a study remain unanswered and unclear.

The study that was conducted did provide some answers to questions pertaining to the interaction of pedagogical context and language in an extracurricular student-centered science learning activity, the FIRST Robotics Challenge. Through semi-structured interviews that included questions pertaining to student team members' and their faculty mentor's experiences in both robotics and the science classroom, elements of language were identified that permitted construction of different Discourses, for both students and their teacher/mentor, pertaining to the science classroom and robotics. These Discourses reflected the contrasting and contradictory identities that both the student team members and their faculty mentor enacted through their accounts of experiences in both contexts.

This having been noted, the students and teachers who participated in this study are not typical science students. The students who participated in this study are part of that minority that participates in every activity offered at their respective schools. There are Science Olympiad competitors, Math Team competitors, Quiz Bowl competitors and noteworthy athletes and actors in their numbers, too.

As already noted, these students are advanced placement science and math students when the advanced courses are available, and take honors-level courses when they are not. The W.A.R. team is composed of the best and brightest from both of the participating schools. In addition, several of the students expressed an interest in being involved in research that might help to improve science teaching and learning. These are academically bright, creative, highly motivated students with a wide range of talents. This being the case, the findings of this study may not be applicable to other populations.

This study focused on only one group of students, participating in only one sort of student-centered group project, the FIRST Robotics Challenge. In addition this study centered on a voluntary extracurricular setting that has little in common with the context of science learning and teaching that is conducted in classrooms. Therefore, care should be taken when trying to generalize this study's findings to other, more typical, science learning/teaching contexts.

The study includes several findings that are well established in science education literature. There are also a number of findings that have only been suggested or predicted by theoretical works and alluded to in the work of some researchers. However, the treatment of student and teacher language through a discourse analysis, and the resulting contentions that the science classrooms of the study participants are made discursively deficient as a result of competing discourses from outside, are new and unconfirmed.

Discourse analysis brings with it a set of limitations and resulting caveats. Discourse analysis never claims to produce a reflection of reality. A discourse analysis is an attempt by one person to construct a version of reality that has limitations placed on it by who the analyst is, and what the circumstances of the analysis are. A discourse analysis is itself a discursive act whose language interacts reflexively with the context that produces it. This reflexive interaction between the language and context of the analysis will make the analysis meaningful in some ways but not in others (Gee, 2005).

I come to this study with biases. I believe strongly that constructivist, student-centered inquiry education is the sort that best prepares students to participate in a democracy. I am a teacher. I have felt for some time that the space in which I formerly provided my students with opportunities for that sort of learning has been shrinking.

As a practitioner involved in research, I have been cautioned to be wary of assigning too much value to my on-the-job experiences, but I am unable to ignore the way that the testing and accountability movements as currently constituted, along with standardization of curricula, have deprived me and my students of the spontaneity that formerly resulted in some of the most meaningful and joyous experiences that have been part of teaching.

I believe that viewing the world exclusively through the twin lenses of science and capitalism produces a distorted view that endangers the very existence of humanity. This view of the world has brought education NCLB, with its own brand of abuses and distortions. I believe that it has privileged a Discourse that views education as a corporate marketized undertaking, designed to promote the righteousness of open, unregulated capitalist markets. I believe that this Discourse casts students as merely a future means of production in the global markets of the twenty-first century. Further, I hold that NCLB has resulted in centralized educational policy and administration that reserves what it touts as objectively standardized metrics as the sole means for assessing progress and attainment of educational goals. It views all other assessments as hokum and takes an almost Old Testament view of accountability for failures to conform or to achieve its standards.

## Personal Reflections

My interests in language predate my time as a graduate student at Georgia State University. These interests began to move toward their current focus during the time that my wife and I served as Peace Corps volunteers in the Solomon Islands, a former protectorate of Great Britain. With a population of about 700,000, the Solomon Islands is an area with very high linguistic diversity where the largest language group claims only about twenty thousand speakers. In the Solomon Islands, several issues of identity and power revolve around language. For example, it was astounding to me that a Solomon Islander would identify himself or herself as a speaker of a particular language rather than as a Solomon Islander or as a man or woman from Santa Isabel Island. Second to this was my surprise at the way that Solomon Islanders regard their incredibly versatile lingua franca, Solomon Islands Pijin; that is, as a broken form of English that is a poor copy of the language spoken by their colonial masters. As a result of these experiences, I began to study pijin languages, and discovered the imbalances of power out of which the vast majority of these contact languages arise. Through this study, I began to see something more than the surface features of language, and to see that language communicated many things at many different levels.

This focus became even sharper during two seminars where I began to read work by Lemke, Gee, Bakhtin and LaTour. A philosophy of education course allowed me to become reacquainted with the dialogical philosophy of Buber and to read some Foucault and Freire. Later, I ventured into the works of Fairclough, Halliday and Wittgenstein. Exposure to these authors influenced the view that I took of my own teaching and shaped the way that I began to view science education. All of these influences led me to believe that making the transition from one way of teaching and learning to another required more than new books, new ancillary materials and another way of decorating a bulletin board. I came to believe that these changes required new ways of considering what could be known and how it could be known and what, in fact it means to know. I began to believe that these different ways of teaching and learning would require a different classroom culture that at its heart would be a creation of language. All of these factors led to this present study.

The findings of this study are, on the one hand, very encouraging. They show how, outside of a school-mandated curriculum, a group of very highly motivated high school students working with equally motivated and very skillful mentors, had a wonderfully fruitful science learning experience. On the other hand, the same students and their faculty mentor produced an account of experiences in public school science classrooms that is devoid of most of the attractive aspects of their extracurricular science learning experience.

In conclusion, this study confirms that open student-centered inquiry is possible under the right conditions. It identifies how a successful inquiry activity looks and sounds, and connects those elements to the context that produced them. It also claims to have identified some of the elements that may make the regular public school classroom unsuitable for open student-centered inquiry science learning. It also claims to have identified the discursive practices that control the science classroom context.

This study warns us that all social institutions, schools among them, are places where different factions vie for power. It warns us that these institutions are spoken into being by the factions that, at any particular time, exert dominant social control over them. It warns us that, when a school or school system declares that “We are a school or system of this, that, or the other,” this declaration is more than a collection of words. It is a declaration of intentions by the groups that hold sway over the schools. It is a declaration of intent by these factions for the very futures of our students.

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# APPENDIXES

## APPENDIX A

PARTICIPANT PROFILES

*Mentors*

Elizabeth Bruce: Faculty Mentor

Elizabeth Bruce is a female science teacher at HS2. At the time of the 2008 FRC season she had been teaching in the county system for three years. She is a veteran teacher with eight years experience, and holds a bachelor's of engineering degree in nuclear engineering and a masters of arts in teaching science. Over the course of her teaching career, she has taught some chemistry, but physics has been her area of concentration. She has taught physics to all levels of students. Elizabeth is Scott Bruce's Wife.

George Mitchell: Faculty Mentor

George Mitchell is a male chemistry teacher at HS1. At the time of the 2008 FRC season, he was beginning his second year teaching in the county system. He is a veteran science teacher with 32 years experience, holds national certification and a master's degree in science education. He has taught chemistry to all levels of students. In addition to teaching Mitchell worked as a quality control chemist with DuPont. Over the course of his teaching career, he has also taught college preparatory physics. He has been a sponsor of FIRST Robotics Challenge and FIRST LegoLeague teams for 7 years. Mitchell also is a certified teacher-training instructor with Educational Testing Service for Advanced Placement Chemistry.

Lenore Pacelli: Faculty Mentor

Lenore Pachelli is a female science teacher at HS1. At the time of the 2008 FRC season has been teaching in the county system for two years. She is a veteran science teacher with 11 years experience; she holds a bachelor's degree in geology and a master's degree in science education. Over the course of her teaching career, she has taught physical science, earth science, environmental science and biology to college preparatory level students. Lenore was the lead sponsor for Science Olympiad at HS1. Lenore is the Brian Pacelli's wife.

Scott Bruce: Engineering Mentor

Scott Bruce is licensed mechanical engineer with a bachelor's and master's of engineering degrees. In 2008, Scott has been practicing engineering for 23 years. He has worked for the last 20 years in conjunction with the nuclear power industry. At the time of the FRC 2008 season he was managing an engineering group that was refitting nuclear facilities in the southeastern United States. Scott is Elizabeth Bruce's husband.

Keith Pacelli: Engineering Mentor

Kieth Pacelli is licensed mechanical engineer with a bachelor's and master's of engineering degrees. In 2008, Kieth had been practicing engineering for 16 years. During his career he has worked on commercial climate control design, automated packaging technology and industrial robotics. Kieth is Lenore Pacelli's husband.

*Student Team Members*

Philemene Aaron

Philemene Aaron is a female team member of W.A.R. In 2008, Philemene Aaron was a sophomore at HS1. The 2008 season was Philemene's first year participating in FRC. During Build, Philemene worked in promotions and logistics. She also helped with programming of computerized control systems and with building the robot. At the 2008 competition, Philemene worked with logistics and was a scout. Philemene was an honor student, member of the math team, Science Olympiad competitor, Beta Club member and winner of Governor's Honors in mathematics.

Stretch Armstrong

Stretch Armstrong is male. In 2008, his sophomore year at HS1, he was a member of W.A.R. 2008 was Stretch's s first year participating in FRC. During Build, Stretch helped to build the robot, and worked some with the promotions team on the team website and with AutoCAD drawings of the robot design. At the 2008, competition, Stretch was a scout, and was instrumental in producing the scouts' data sheet. Stretch Armstrong as an honor student, member of the math team, Science Olympiad competitor, swim team, cross country and track team member. He has appeared in five drama productions at HS1.

Lynn Brady

Lynn Brady is female. In 2008, she was a junior at HS2. 2008 was Lynn's second year participating in FRC. During Build for both the 2007 and 2008 seasons, Lynn was involved in logistics and promotion. During the 2007 and 2008 competitions, Lynn was a scout and helped with logistics. In 2008 she was also a RoboCoach.

Velvet Bruce

Velvet Bruce is female. In 2008, she was a junior at HS1. 2008 was Velvet's second year participating in FRC. In 2007 and 2008 Velvet was involved in promotion and logistics. In 2008, Velvet was involved in programming computerized control systems. At the 2008 competition, Velvet was a RoboCoach and scout. Velvet was an honor student and member of Beta club. Velvet is also an avid dressage competitor.

Hans Fowler

Hans Fowler is male. In 2008, his junior year at HS1, Hans Fowler was a member of W.A.R. 2008 was Hans' first year participating in FRC. During the 2008 Build, Hans was involved in building the robot and programming of computer control systems. At the 2008 competition, Hans was a scout. Hans was an honor student, member of the math team, Science Olympiad competitor, cross country team member and was appointed the student-at-large to consult the county board of education on student issues.

Shaggy Jones

Shaggy Jones is male. In 2008, his senior year at HS2, Shaggy Jones was a member of W.A.R. 2008 was Shaggy's second year participating in FRC. In 2007, During Build, Shaggy was involved in building the robot and in programming computerized control systems. At the 2007 competition, he was a scout. During the 2008 season, Shaggy was involved in building the robot and programming computerized control systems. At the 2008 competition, Shaggy was the head Scout. Shaggy was an enthusiastic gamer.

Pavlova Kinsky

Pavlova Kinsky is female. In 2008, she was a junior at HS1. 2008 was Pavlova' s first year participating in FRC. During Build, Pavlova was involved in promotions and logistics she was the lead writer for the NASA grant application, and helped Ms. Bruce gather documentation to support the NASA grant application. Pavlova was an honor student and member of Beta club. Pavlova is also an avid dancer.

Patrick Limemann

Patrick Limemann is male. In 2008, his senior year at HS2, Patrick Limemann was a member of W.A.R. 2008 was Patrick's second year participating in FRC. In 2007, During Build, Patrick was involved in building the robot and. At the 2007 competition, he worked in the pit. During the 2008 Build, Patrick was involved in building the robot and programming computerized control systems and worked on the AutoCAD drawings of the robot design. At the 2008 competition, Patrick worked in the pit and was the W.A.R.'s head driver. Patrick is a self-professed gearhead and lover of Harley Davidson Motor cycles.

Patrick Pitcher

Patrick Pitcher is male. In 2008, his junior year at HS2, Patrick was a member of W.A.R. 2008 was Patrick's first year participating in FRC. During the 2008 Build, Patrick was involved in building the robot, programming computerized control systems and he worked on the AutoCAD drawings of the robot design. At the 2008 competition, Patrick worked in the pit and was the W.A.R.'s assistant driver and competition coach. Patrick was an enthusiastic gamer.

Nolan Strange

Nolan Strange is male. In 2008, his junior year at HS2, Nolan was a member of W.A.R. 2008 was Nolan's first year participating in FRC. During the 2008 Build, Nolan was involved in building the robot, he worked on the AutoCAD drawings of the robot design and helped to program the computerized control system of the robot. At the 2008 competition, Nolan was a scout and the team's safety captain. Nolan was on the cross-country team at HS2.

Faith Wedgwood

Faith Wedgwood is female. In 2008, she was a junior at HS1. 2008 was Faith' s first year participating in FRC. During the 2008 Build, Faith was involved in promotions and logistics she assisted in writing the NASA grant application. She also worked some on building the robot. At the 2008 competition, Faith worked in logistics and promotions. Faith was an honor student and member of Beta club. She was also a Science Olympiad competitor and sang in the mixed chorus at HS1.

Hope Wedgwood

Hope Wedgwood is female. In 2008, she was a junior at HS1. 2008 was Hope' s first year participating in FRC. During the 2008 Build, Hope was involved in promotions and logistics she assisted in writing the NASA grant application. She also worked some on building the robot. At the 2008 competition, Faith worked in logistics and promotions Hope was an honor student and member of Beta club. She was also a Science Olympiad competitor.

# APPENDIX B

**Essential Features of Classroom Inquiry and Their Variations**

| Essential Feature | Variation | | | |
|---|---|---|---|---|
| 1. Learner engages in scientifically oriented questions | Learner poses questions | Learner selects among questions, poses new questions | Learner sharpens or clarifies question provided by teacher, materials, or other sources | Learner engages in questions provided by teacher, materials, or other sources |
| 2. Learner gives priority to **evidence** in responding to questions | Learner determines what constitutes evidence and collects it | Learner directed to collect certain data | Learner given data and asked to analyze | Learner given data and told how to analyze |
| 3. Learner formulates **explanations** from evidence | Learner formulates explanation after summarizing evidence | Learner guided in process of formulating explanations from evidence | Learner given possible ways to use evidence to formulate explanation | Learner provided with evidence |
| 4. Learner connects explanations to scientific knowledge | Learner independently examines resources and forms the links to explanations | Learner directed toward areas and sources of scientific knowledge | Learner given possible connections | |
| 5. Learner communicates and justifies explanations | Learner forms reasonable and logical argument to communicate explanations | Learner coached in development of communication | Learner given broad guidelines to sharpen communication | Learner given steps and procedures for communication |

More ◄——— Amount of Learner Self-Direction ———► Less

Less ◄——— Amount of Direction from Teacher or Material ———► More

*Note*. Adapted from *Inquiry and the National Education Standards*, p. 29 Copyright 2000 by the National Research Council and used by permission of NRC.

APPENDIX C

INTERVIEW QUESTIONS

Student Team Members' Interviews

Philemene Aaron

Question A: Could you tell me about some things that you think that you might carry forward from you experience in robotics into your later life?

Question B: Can you describe the nature of that collaboration?

Question C: You ended up with one robot though. With all of these ideas, how did this happen?

Question D: How would you describe the limitations that were placed on you in terms of what your design might be?

Question E: How would you compare what goes on with the robotics team with what goes on in a science lab where you're doing some sort of a hands-on activity?

Question F: What was the source of the intensity? It was intense, why?

Question G: How would you compare the role of a science teacher with the role of a sponsor or mentor with the robotics team?

Question H: What do you mean by "working from nothing"?

Question I: How would you compare the relationships that you have with people in your science classes with the relationships that you have with members of the robotics team?

Question J: From what you saw, which made up a larger percentage of members of the robotics team, girls or boys?

Question K: Why do you think this is so?

Question L: What did you do on the team?

Question M: At the competition?

Question N: Were you the only scout?

Question O: Did you work together with the other scouts in compiling the report?

Question P: Could you describe how you worked together to compile the report?

Question Q: Did each person always agree as to which robots were strongest and best suited to helping the team?

Question R: When you didn't agree did you make any attempt to reach agreement? If so, how?

Question S: All right, Philemene, that's all that I have to ask you for now. Do you have any questions for me?

Stretch Armstrong:

Question A: Can you compare what you do with the robotics team with what you do in your science class?

Question B: Could you talk a little bit more about the "couple of steps forward" and "applying the skills"?

Question C: So, you're saying that you learn science knowledge in both places? Is that correct? Have you ever produced anything in a science class that is like the robot that you produced in robotics club?

Question D: Could you talk about the competitive aspect of robotics?

Question E: Well, in robotics you are preparing a robot for a competition and judging by you other comments, science classes are not about preparing something for a competition, right?

Question F: So, what kind of things do you feel that you understand more about?

Question G: What's the result of dealing with this "nit-picky stuff"?

Question H: How do you deal with the fact that "everything doesn't work the first time"?

Question I: Could you talk a little about the relationships that you had with your robotics team members and the relationships that you have with your science classmates?

Question J: So, what about science class? In science class what are the relationships like?

Question K: In talking about robotics relationships you mentioned cooperation. Could you talk more about cooperation?

Question L: In class it's not so much", what ?

Question M: Going back a little bit. What is the "it" that "you can't do on your own"?

Question N: Could you say more about student teacher relationships?

Question O: What did you do before competition?

Question P: You said that there were a lot of ideas. How did the group finally decide what to do?

Question Q: How did you finally decide on a design?

Question R: Stretch, thanks for giving me your time and answering my questions. Do you have any questions for me?

Hans Fowler:

Question A: Do you think that you learned in robotics that you might be able to carry into your later life?

Question B: Could you talk about that a little bit more?

Question C: Describe, if you will, the process of how you ended up with the robot that you took to competition.

Question D: Could you describe a little bit more of what the process was that led to the robot. How did the design result?

Question E: Tell me more about the brainstorming. How did that go?

Question F: So, how did you end up with the robot that you took to competition?

Question G: How would you compare what goes on with the robotics team with what you do in a science class lab activity?

Question H: How would you compare the sort of relationships that you have with science class classmates with those that you have with robotics team teammates?

Question I: What about the relationship between a science teacher and a robotics team sponsor or mentor?

Question J: Short and sweet as usual, Hans. Do you have any questions for me?

Shaggy Jones:

Question A: Could you talk about your experiences on the robotics team and in a science class?

Question B: What do you think that you've gained from your experiences in robotics and how do these compare with what you have gotten from your science classes?

Question C: So what do you mean by the stuff you do in physics is not as extensive, is that the word you used, as what you do in physics? So could you talk about what the extensive aspect of what you do in robotics does that you may not do in physics?

Question D: So, why are the things that you do in physics class really different from Robotics?

Question E: Ok. How do the relationships that you have with your classmates, in science class, compare with the sorts of relationships that you have with your robotics teammates?

Question F: Could you talk about why you think those different kinds of relationships develop?

Question G: Do you see the first day of school as being an equally auspicious time to start relationships and make new friends?

Question H: You mentioned that you have to be there. Does that dynamic affect the relationship with your teacher in class?

Question I: I mean, I'm interested in Ms. Bruce too, but she's the robo-queen, so in addition to her cast your mind back to your other science teachers as well.

Question J: Why do you enjoy the robotics team members?

Question K: How does the relationship that you would have with a robotics team sponsor or mentor compared to the relationship that you would have with a classroom teacher particularly a science teacher?

Question L: Those other people; how would the project of building a robot be for an individual as opposed to a member of a group?

Question M: So, at the end of the project, how would you compare your level; of expertise in some of those areas that you just named as compared with when you began?

Question N: Could you talk to me about the idea of team?

Question O: During the competition, one of the things that I saw with you was it look as though you were in charge of scouting. It seemed that you ran that end of the thing. Could you talk a little bit about how you and the other scouts developed your methods for scouting the other robots? What was your process?

Question P: One of the things that I got as a document was a scouting sheet that appeared to be made by FIRST. You guys had them on clipboards. I noticed that in addition to these Stretch, from High School #1, did detailed sketches of the robots. You guys circulated these among the team of scouts. Another thing that you guys developed was a metric that compared the points that a robot earned to points that the robot lost through penalties. So, it appears that you used what FIRST provided, but you also added some assessment criteria of your own. Could you talk about this?

Question Q: What is the thing that you take away from this other than the hands on experience that you have mentioned before?

Question R: The design for the robot, what do you think the main shortcoming was?

Pavlova Kinsky:

Question A: Please describe what you did with the robotics team. So, funding and promotion?

Question B: Were there any experiences from robotics that you think will be useful to you in later life?

Question C: OK, so what was the “field” that you had never had experience in before?

Question D: You have talked about “all of these ideas”, but in the end, you built only one robot. Can you talk about how you got from these many ideas to one robot?

Question E: You’ve talk about limits with the budget and limits placed on you by time, then you started to talk about design limitations. You mentioned that you started with many ideas, could you describe the process that you used to choose the ideas that were ultimately put into the one robot design?

Question F: Could you describe the sorts of relationships that you had with members of the robotics team as compared with the relationships that you have with members of a lab group in a science class?

Question G: How does the way that you described your cooperation in robotics compare with the way that you work with your lab partners in science class?

Question H: Could you talk about the roles that science teachers play in the science classroom and the role that sponsors and mentors play in robotics?

Question I: How would you compare the relationships that you have with classroom science teachers with the relationships that you have with robotics team sponsors and mentors?

Question K: Who was in the minority on the robotics team, males or females?

Question L: Why do you think there are fewer girls than boys on the team?

Question M: What do you mean by the "competitive aspect"?

Question N: You did not actually attend competition, right? So your contributions to the team were in the lead up to competition?

Question O: Thank you very much for your time and cooperation. Do you have any questions for me?

<u>Patrick Limemann</u>:

Question A: What did you learn as a member of the robotics team?

Question B: Is this something that you can carry into your life after high school?

Question C: What kinds of things did you learn?

Question D: How did you decide what you would do for a design?

Question E: Can you describe how you decided what ideas you would use?

Question F: How might this discussion go? How did you do it?

Question G: But how did you finally decide. You said that you had a lot of ideas,

but you built only one robot. How did you decide?

Question H: So, do you think that you'll carry these things into your later life?

Question I: Could you please tell me more about these things?

Question J: What sort of help do the engineers give the students that are on the team?

Question K: You mentioned science class. Can you tell me more about what you do in science classes; how would you compare science class with robotics? Could you talk about something that you did in science class that was hands on and similar to robotics?

Question L: Do you mean that you don't know what you're supposed to do in lab or that you don't understand the directions?

Question M: How would you compare the relationships that you have with your classroom science teachers and the relationships that you have with the robotics sponsors?

Question N: Yes? Can you say more?

Question O: Patrick, we have covered a lot of ground. Do you have anything more that you would like to say or do you have any questions that you would like to ask?

<u>Patrick Pitcher</u>:

Question A: Patrick, I want this to be a conversation about the robotics team, and how you feel and think about your experiences with the team.

Question B: Is this something that you can carry into your life after high school?

Question C: What kinds of things did you learn?

Question D: How did you decide what you would do for a design?

Question E: Can you describe how you decided what ideas you would use?

Question F: How might this discussion go? How did you do it?

Question G: But how did you finally decide. You said that you had a lot of ideas, but you built only one robot. How did you decide?

Question H: Could you please tell me more about these things?

Question I: What sort of help do the engineers give the students that are on the team?

Question J: You mentioned science class. Can you tell me more about what you do in science classes; how would you compare science class with robotics? Could you talk about something that you did in science class that was hands on?

Question K: Do you mean that you don't know what you're supposed to do in lab or that you don't understand the directions.

Question J: How would you compare the relationships that you have with your classroom science teachers and the relationships that you have with the robotics sponsors?

Question K: Yes? Can you say more?

Question L: Patrick, we have covered a lot of ground. Do you have anything more that you would like to say or do you have any questions that you'd like to ask me.

Faith Wedgwood:

Question A: Do you feel that you learned things in robotics that you feel will be useful to you later on in life?

Question B: What about from science classes; what do you think you might carry away from what you learn in science class?

Question C: Ok, What was your function with the team?

Question D: Were you a part of the planning of the design of the robot?

Question E: Can you describe the process of scouting?

Question F: On the robotics team, which was in the majority, boys or girls?

Question G: How did you see the roles of boys and girls on the team?

Question H: What makes something a "girlie thing"?

Question I: Well, thank you very much for your time. Do you have any questions for me?

Hope Wedgwood:

Question A: Do you feel that you learned things in robotics that you feel will be useful to you later on in life?

Question B: What about from science classes; what do you think you might carry away from what you learn in science class?

Question C: Ok, What was your function with the team?

Question D: Were you a part of the planning of the design of the robot?

Question E: Can you describe the process of scouting?

Question F: So, what sorts of things were you interested in as you observed the robots?

Question G: How did you know that those would be the things to look for?

Question H: How would you compare the relationships that you have with your robotics teammates with the relationships that you have with classmates in your science class?

Question I: So, how would you compare the relationship that you have with your robotics sponsors and mentors to those that you have with your science teachers?

Question J: On the first day that the robotics team met, do you think that anyone on the team knew what the final robot would look like?

Question K: On the robotics team, which was in the majority, boys or girls?

Question L: How did you see the roles of boys and girls on the team?

Question M: What makes something a "girlie thing"?

Question N: Well, thank you very much for your time. Do you have any questions for me?

Mentor Interviews

George Mitchell:

Question A: Could you talk about how you feel your role as a teacher in a typical science class compares with your role as a robotics sponsor?

Question B: You mentioned that you felt that the atmosphere for robotics was "more relaxed" than it was in a science class and that you role as a robotics sponsor was "not so official". Could you talk more about the reasons those differences in the robotics team and the science classroom?

Question C: In several ways, you have alluded to the differences between the sort of relationships that you have with your students in your chemistry classes and the students in robotics. You have also referred to your role in sciences classes as teacher and distinguished that role from that as a facilitator or mentor in robotics. Could you talk about these distinctions?

Question D: Do you feel that the sorts of tasks that we give students in robotics and in science class lend themselves to the sorts of independent learning that you have just mentioned?

Question E: Judging by what you have said there are some differences between the patterns that we find students and teachers/sponsors/mentors following in science classes and robotics. Why do you think that these patterns are different?

Question F: I know that you are not currently a practicing scientist, but you have worked for a while with DuPont in their research and development and quality control labs. If you take the experiences that the students have in the robotics program and the experience that students have in science classes. Broadly speaking, which would you say gives them a better perspective and involves them in activities that are most similar to what practicing scientists and practicing engineer.

Question G: You mentioned a time constraint that is placed on the robotics program. Are their any other constraints, other than those imposed by FIRST, that you see as important for establishing the character of the robotics experience.

Question H: During your answers, you have mentioned discussions and agreement among the robotics team members. Is it your experience that the robotics team comes into a season with one idea for the robot after all the team builds only one robot?

Question I: George we've covered a lot of ground today. Do you have any questions for me?

Scott Bruce:

Question A: Just in general, what do you see when you see these kids confront the problems of designing and building a robot?

Question B: You're giving an account that is really not so different from the ones that the kids give. One of the patterns that I have seen as I've been transcribing the kids' answers to interview questions is that when they talk about the robotics team there is evidence of strong ownership in the project. You've already mentioned this in your answers to my questions. I'd like to know, do engineers take strong ownership in the projects that they are involved in?

# APPENDIX D

Sky Bandits

| Paste Picture Here | |
|---|---|
| | School: 2038 |
| | Contact Name: |
| | Scout Name: |
| | Date: |
| | excellent herder<br>Comments: |

| Attribute | Strength (1 thru 5) | | | | | |
|---|---|---|---|---|---|---|
| | 1 (none) | 2 (weak) | 3 (OK) | 4 (strong) | 5 (superior) | Score |
| Hybrid | | | ✓ | | | |
| Speed/Agility | | | | ✓ | | |
| Trackball Removing | | | | ✓ | | |
| Trackball Hurdling | ✓ | | | | | |
| Trackball Placing | ✓ | | | | | |

Match Observations

| Match Number | Partners | Opponents | Team Score | | Opponent Score |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

One of alliances
- 2WD (omni front, std back)
- puncher (popper)
- herding arms
- 6-7 mph
- can cross 2 lines in autonomous mode
- scored 40 pts on own

Sky Bandits

| Paste Picture Here | School: 2038 |
|---|---|
| | Contact Name: |
| | Scout Name: |
| | Date: |
| | excellent herder<br>Comments: |

| Attribute | Strength (1 thru 5) | | | | | |
|---|---|---|---|---|---|---|
| | 1 (none) | 2 (weak) | 3 (OK) | 4 (strong) | 5 (superior) | Score |
| Hybrid | | | ✓ | | | |
| Speed/Agility | | | | ✓ | | |
| Trackball Removing | | | | ✓ | | |
| Trackball Hurdling | ✓ | | | | | |
| Trackball Placing | ✓ | | | | | |

Match Observations

| Match Number | Partners | Opponents | Team Score | | Opponent Score |
|---|---|---|---|---|---|
| | | | | | |
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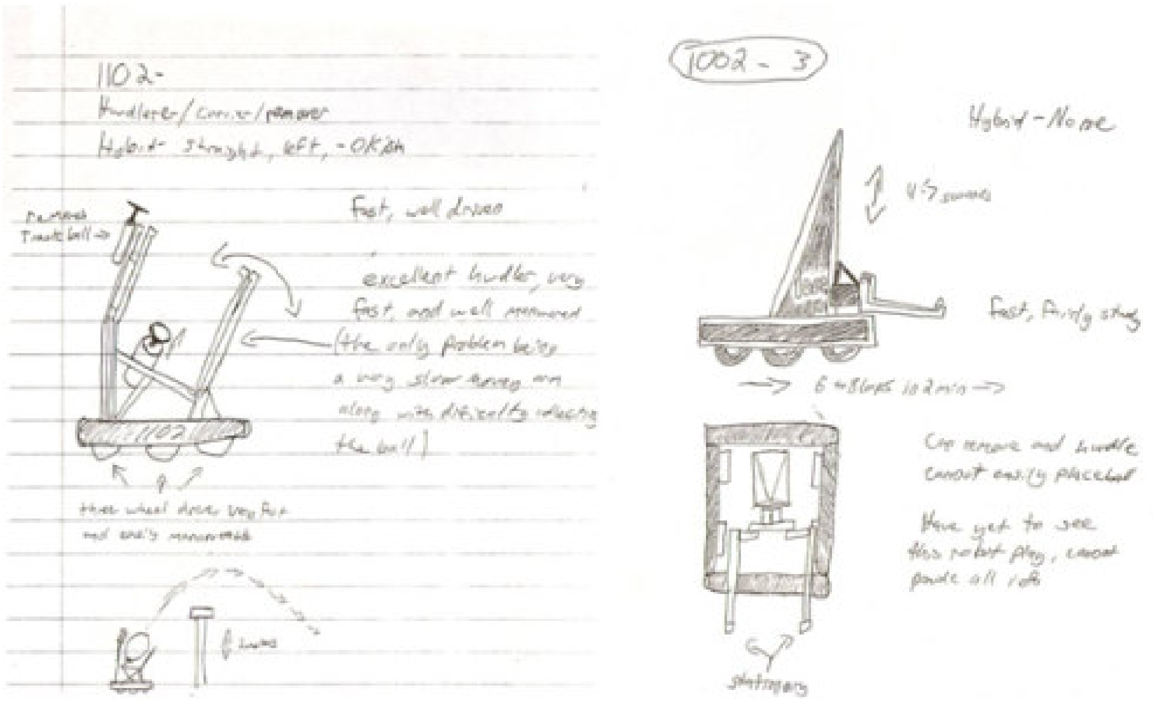
One of alliances
- 2WD (omni front, std back)
- puncher (popper)
- herding arms
- 6-7 mph
- can cross 2 lines in autonomous mode
- scored 40 pts on own

| | |
|---|---|
| Paste Picture Here | Aiken County School: 1102 |
| | Contact Name: |
| | Scout Name: Ka... |
| | Date: |
| |  Comments: launcher, cool...... Definite crowd pleaser, though not the most practical.... |

| Attribute | Strength (1 thru 5) | | | | | |
|---|---|---|---|---|---|---|
| | 1 (none) | 2 (weak) | 3 (OK) | 4 (strong) | 5 (superior) | Score |
| Hybrid | ✓ | | | | | |
| Speed/Agility | | | | ✓ | | |
| Trackball Removing | | | | ✓ | | |
| Trackball Hurdling | | | | ✓ | | |
| Trackball Placing | | ✓ | | | | |

Match Observations

| Match Number | Partners | Opponents | Team Score | | Opponent Score |
|---|---|---|---|---|---|
| 1 | 343, 1282 | 1002 281 | 70 | 2 | 96 |
| | " " | " " | 54 | | 10 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |


Fast, well driven
excellent hurdler, very
1002 - 3
Hybrid - None
Have yet to see
stationary

APPENDIX E

# W.A.R. MATCH SCORE RECAP

| Match Number | Partners | Scored / Penalized | | Opponents | Scored / Penalized |
|---|---|---|---|---|---|
| 13 | W.A.R. | 18 / 2 | | 1102 | 20 / 8 |
| | 1746 | 24 / 8 | | 2362 | 12 / 0 |
| | 1612 | 2 / 0 | | 1533 | 14 / 6 |
| | Total | 44 / 10 | | Total | 46 / 14 |
| | Net Score | 34 | | Net Score | 32 |

# APPENDIX F

## Synopsis of Findings, Reform Documents and Research Literature

| Findings | Reform Documents | Research Literature |
|---|---|---|
| Students use scientific language in context of inquiry activity. | a. AAAS (1990)<br>b. AAAS (1993)<br>c. NRC (1996)<br>d. NRC (2000) | Brown (2006); Dawes (2004); Driver et al. (2000); Duschl & Osborne (2002); Hogan et al. (1999);<br>Mercer, Wegerif, Dawes (1999); Mercer et al. (2004); Moje et al. (2001); Rosebery, Warren, Conant, (1992); Roth (1992); Roth & Bowen (1995); Sutton (1996); Roth & Lawless (2002); Salyer (2000); Scott et al. (2006); Tobin et al. (1997); Warren, et al. (2001); Warren & Rosebery (1996); Westby et al. (1999); Woodruff & Meyer (1997); Young (2005); |
| Students engaged in the practices and embraced tha values of practicing scientists. | a. AAAS (1990)<br>b. AAAS (1993)<br>c. NRC (1996)<br>d. NRC (2000) | Driver et al (2000); Duschl & Osborne (2002); Watson et al. (2004) |
| Students develop identity of themselves both individually and as a group as owners of their inquiry project and as members of a community of scientists/engineers. | a. AAAS (1990)<br>b. AAAS (1993)<br>c. NRC (1996)<br>d. NRC (2000) | Brown (2006), (2004); Duschl & Osborne (2002); Gee (2004); Gutierrez (1999); Hellermann et al. (2001); Hogan et al. (1999); Kawasaki et al. (2004); Kelly et al. (2000); Lee (2001); Mercer et al. (1999); Mueller (2002); Roth (1993); Roth & Bowen (1995); Ritchie & Rigano (2002); Ritchie & Tobin (2001); Salyer (2000); Shepardson & Britsch (2006); Tobin et al. (1997); Scott (1998); Sutton (1996); Warren & Rosebery, (1996); Woodruff & Meyer (1997); Warren et al. (2001) |
| Language used by female team members of W.A.R. was used to construct a different and marginal identity when compared with the identities constructed by male team members. | a. AAAS (1990)*<br>b. AAAS (1993)* | Gee (2004); *Gallas et al. (1996); *Gutierrez et al. (1999); Kahveci, et al. (2008); *Lee (2001); *Lee & Fradd (2003); Lemke (2001), Lemke (1990) |

* Addresses groups that when engaging in inquiry may be marginalized by aspects of other Discourses. These do not address female science students as a marginalized group of science-learners specifically.