Toward a More Complete Theory of Design-Based Science Teaching and Learning: Recognizing the Voices of Students of Color

A Qualifying Paper

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ABSTRACT

The aim of this review is to explore the question of whose Discursive practices count within primary science education and science education research. To examine this question, this review situates science Discursive practices within the dichotomous relationship of dominant and non-dominant and uses these categories to theorize, examine, and challenge the ways that race and racism implicitly and explicitly impact school views of scientific thinking and knowledge. The goal of this exploration is to advocate for the implementation of alternative methods of study and analysis when investigating the Discursive practices of children from communities of color, particularly within the context of design-based science activities.

This review utilizes Gee's (1996) definition of Discourse: "a socially accepted association among ways of using language, other symbolic expression, and artifacts, of thinking, feeling, believing, valuing, and acting that can be used to identify oneself as a member of a socially meaningful group or social network" (p. 131). This review extends Gee's definition with a focus on the necessity of having one's Discursive practices recognized by those already with membership into a social network, thus situating Discourse within a dominant and non-dominant relationship. I will use this review to examine how the everyday, normal, or typical view of science Discourse (dominant view) has been reproduced within classrooms with a particular focus of children from communities of color.

With the increased recognition of design-based science as a pedagogical approach to teaching science, I contend that the experiences of all children need to be investigated in order to develop a more complete theory of design-based science teaching and learning. Designing explorations into what these children bring to design-based science activities will assist in the process of ensuring academic success for all students.

1.0 INTRODUCTION

The goal of this review is to examine the issue of *whose Discourse is recognized* within science education and science education research. To examine this question, this review will situate Discursive practices within a dichotomous relationship between dominant and non-dominant scientific practices[1] and use these categories to theorize, examine, and challenge the ways that race and racism implicitly and explicitly impact school recognition of the Discursive practices of children from communities of color[2]. Exploring the ways in which these children have been positioned in previous and current theories of learning will assist in suggesting alternative methods for future investigations, particularly within the context of design-based science classrooms[3]. The purpose of this examination is to conceptualize how science Discourse can be seen through issues of racial and linguistic power, and how this conceptualization can be utilized in the developing theories of design-based science teaching and learning. The ever-increasing interest in the successful academic performance in science-related fields for children from communities of color influences the need for exploring this research. Further, these new research practices could help to envision future investigations of children's

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[1] In science education literature, these practices are often described as "everyday and scientific" (Ballenger, 1997; Herrenkohl & Guerra, 1998; Rosebery, Warren, & Conant, 1992). I utilize the terminology of dominant and non-dominant to introduce the examination of Discourse through the lens of racial and linguistic power.

[2] I use a United States 'traditional' term, communities or students of color, to represent children from racial or communal backgrounds other than European descent. Despite my use of students of color, I recognize that the use of the term "children from non-dominant communities" would have also been appropriate because it explicitly acknowledges issues of power and power relations (Gutiérrez, 2008). I will refer to these children as "marginalized youths" due to the historical treatment and perceptions surrounding them (Lee, 1994).

[3] For the purpose of this review, design-based science refers to the teaching of science through activities that emphasize engineering and technology (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naama, 2005). Design-based science activities may also be referred to in the literature as engineering design and/or technology.

Discursive practices, beyond communities of color, where all power differentials and dynamics can be acknowledged.

Throughout this review, I will use Gee's (1996) definition of big "D" Discourse: "a socially accepted association among ways of using language, other symbolic expression, and artifacts, of thinking, feeling, believing, valuing and acting that can be used to identify oneself as a member of a socially meaningful group or social network" (Gee, 1996, p. 131). Analyzing this definition further, it is evident how Discourse, or the speech acts and interactions between individuals, could be conceptualized through issues of power. The necessity of having one's Discursive practices recognized by the socially accepted association of a group explicitly situates this interaction within a dominant and non-dominant relationship. The very definition of Discourse assumes the notion that people share everyday, normal, or typical theories on the world, and in this case the scientific and engineering design worlds. I will use this review to examine how the everyday, normal, or typical view of science Discourse has been reproduced within classrooms with a particular focus on children from communities of color.

Discourse as the socially situated integration of language and practice will be differentiated from discourse – dialogue, conversation, and stories – by the use of a capital "D" and lower case "d" respectively after Gee (1999). A focus on scientific Discourse highlights the importance of children knowing how to do and talk "school" science, as well as how to understand scientific content, in order to be successful in school science. Being recognized as engaging in school science includes particular ways of manipulating materials, making observations, interpreting and verifying evidence, and constructing ideas to make sense of the world. Being recognized as talking school science involves learning how to articulate explanations, construct arguments, and evaluate different points of view (Halliday & Martin, 1993; Lemke, 1990). These Discursive demands can be further complicated when students are engaged in design-based activities, as opposed to inquiry-based science activities[4], because students are expected to conceptualize, represent, and communicate their knowledge in additional ways and for different purposes (Kelly & Brown, 2003; Layton, 1993).

For example, Schauble, Klopfer, and Raghavan (1991) differentiate between the purpose of science experiments (inquiry-based) and the purpose of engineering experiments (design-based). They contend that the goal of science experiments is to understand the relation among cause and effects, while engineering experiments are characterized by the goal of manipulating variables to produce a desired outcome. These distinctions require children to differentiate the Discursive practices of each approach and use the appropriate behaviors within their specified and relevant contexts.

By focusing on the appropriate speech acts and interactions within school science, this review will construct a conceptualization of how marginalized youths may experience and approach learning in design-based science environments. Both the National Research Council's (NRC) National Science Standards (1996) and the American Association for the Advancement in Science's (AAAS) Project 2061 (1993) have identified learning standards for students in grades K-8 that emphasize knowing how to do and talk science – both considered components of science Discourse as defined by this review. Thus, Discourse has had a national impact on the value our schools and society,

[4] Inquiry-based science is a pedagogical approach to teaching science where student examinations and investigations are the catalyst for acquiring knowledge. Though similar in nature, design-based science uses the idea of design or engineering design as the source of constructing science knowledge. All design-based science activities are structured around an engineering design process (Fortus, 2003).

in general, place on students' abilities to communicate their ideas, thoughts, and interpretations within the science classroom as an integral component of their Discourse acquisition and a demonstration of scientific literacy. As a result, science Discourse is evidence in the identification of learners' authentic membership in the scientific community.

At the same time, however, the recognition of Discursive practices with a limited and limiting view has perpetuated a systematic practice of excluding large populations of children developing in and identifying with science, with a majority of these from children coming from communities of color (Warren, Ogonwki, & Pothier, 2005). This concepts places emphasis on my original question: *whose Discourse is recognized* in science education and science education research? Brickhouse (1994) asserts that schools often reject the variations in Discursive practices demonstrated by marginalized youths, often subjugating them to tracking into lower ability groups and lower expectations in the science classrooms when their practices do not fit within the socially accepted Discursive practices. She highlights the disconnect that often exists between school science knowledge (i.e., the dominant) and students' experiential knowledge (i.e., the non-dominant). School science is often presented to students as 'facts,' while dismissing the conceptualizations that students bring to school.

A college freshman[5] elaborates on her disconnect with chemistry as a course that has little to do with making sense of the world as she is asked the question, "what is chemistry?'

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[5] Unfortunately, the race of this student was identified within the article. Although the race of this student would have been important for this review, I found the student's answer important in order to highlight the implicit dominant / non-dominant relationship that she recognizes between a student and a teacher within a science classroom.

> It’s a subject that some things you aren’t too sure about. I mean, no one is really definite about. You must have to believe that they’re [the instructors] right. And, um, a lot of things are real abstract. You just have to kinda deal with it. (Brickouse, 1994, p. 407)

The professional science community has played a powerful role in promoting the cultural and racial stratification and marginalization because it recognizes and privileges a certain kind of Discourse to which only a few learners have access (Delpit, 1998; Nasir, Rosebery, Warren, & Lee, 2006; Yerrick, 2000). For example, Brown (2005) suggests that students who use scientifically sophisticated words and vocabulary are recognized by school personnel as intellectually capable of membership into the scientific community and are encouraged and supported to eventually develop a self-image of scientific accomplishment and scientific intelligence. The importance of external recognition in this process is that students, most often children from communities of color (Brown, 2005), deemed unscientific begin to see themselves as scientifically inferior in the classroom, and this develops a disconnection with scientific identities (Brickhouse, 1994; Seiler, 2001).

Brickhouse, lowery, and Schultz (2000) used the case studies of four, middle school African American girls to examine school science’s recognition of Discursive practices. The researchers described how school personnel encouraged girls whose Discursive practices were aligned with school science, or the dominant view of science, to take advanced science courses, while alienating the girls who were engaged in practices that were not recognized as relevant to the dominant view of school science (e.g., rock collecting and repairing x-ray machines). The young women who were encouraged to develop a scientific identity were more interested in science than the young women who were marginalized, but they did not posses the Discursive practices that *count* in a science classroom. For example, one student, Sandy, was described as "good at figuring things out" (p. 455) and entrenched in commonsense science due to her everyday experiences of working with her father who repaired mechanical devices. Sandy's out-of-school science-related experiences were considered by her teacher as valuable for the minimal number of experiences with lab experiments that required problem-solving skills. Unfortunately, though, Sandy's experiential knowledge was not valued during the frequent teacher-centered science activities. In contrast, another student, Sheela, is described as "good in science because she is good in all school subjects" (p. 453) and she functioned well in student-led and teacher-led activities. Sandy's desire to engage with school science in her familiar exploratory procedures was often in competition with the classroom practices of teacher and textbook-centered activities focused on 'factual knowledge.' Although Sandy would typically be classified as a student who did not succeed in school science or was disconnected from science, I argue against such a claim. Sandy was indeed deeply connected with science, but her scientific ways of knowing or thinking, or Discourse, were not counted in school science.

Brown's (2005) claim, mentioned above, emphasizes the harmful potential that exists for students when thinking and talk is judged and labeled in dichotomous ways: *either* everyday or scientific. Everyday thinking and talking are considered to be "concrete, familiar, and commonplace" (Warren, Ogonowski, & Pothier, 2005, p. 119), whereas scientific thinking and talk are considered "precise, complex, and abstract"

(Warren et al., 2005, p. 119). Gee (2008) provides an example of how convoluted this distinction can be as he describes two elementary school children's use of everyday language while discussing the science of what makes things rust:

> Jill: But if we didn't put the metal things on there, it wouldn't be all rusty.
>
> Philip: But if we didn't put the water on there, it wouldn't be all rusty. (Gee, 2008, p. 57)

This example is important because the students use the same 'everyday' phrase of "be all rusty" to describe an observation, but are actually describing two different 'scientific' phenomena. Jill is describing a situation where rusty objects are causing other objects to "be all rusty" by physical contact, as opposed to Philip who is describing how water causes things to "be all rusty" through a chemical reaction. Gee (2008) describes the potential for this discussion to become a centerpiece of a classroom discussion and accentuate the students' scientific thinking. In addition, teachers could utilize these kinds of 'scientific' thinking to support students' acquisition of a more 'scientific' school Discourse that would differentiate between the processes of physical contact versus a chemical reaction. Failure to recognize the science in this kind of thinking supports and reinforces feelings of scientific inferiority on the part of the students who, as a result, remain identified within a limited and limiting view of scientific Discursive practices.

Limited opportunities to learn and engage in science Discourse that *counts* in school have served as barriers for many children who might otherwise pursue careers in science and engineering (Moje, Collazo, Carrillo, & Marx, 2001) and have created a mystique around these technical fields that continues to be reinforced through differential educational opportunities for marginalized youth (Lemke, 1990). This mystique supports a view of science, and related fields such as engineering, as an inaccessible and exclusive community.

In order to further explore everyday and scientific practices and behaviors, Section Two of this paper will examine and synthesize varied definitions of Discourses and situate Discursive practices within this dichotomous relationship. In addition, the process whereby scientific Discursive behaviors and ideas are made to seem 'normal,' also referred to as normalization, will be examined. Section Three will conceptualize the idea of an engineering design Discourse for elementary and middle school classrooms. Next, in Section Four, we will examine the normalization of Discursive practices through racial contexts or a process of racialization, in order to further analyze how students are rewarded or punished for conforming to or deviating from these normalized ideals. Section Five will provide a brief exploration into the discontinuous and continuous perspectives of science in communities of color and use it to examine the construction of 'normal' practices and thinking processes. Finally, Section Six will examine the broader implications of recognizing the Discursive practices of students of color.

2.0 CONCEPTUALIZING DISCOURSE

Discourse has been conceptualized in a number of different ways. A synthesis of these conceptualizations and how they relate to students of color can inform future investigations on everyday and scientific Discursive practices. One of the most useful and important views on Discourse comes from the work of James Paul Gee. Gee (1999) extends his definition of Discourse previously presented and establishes it as the "socially accepted integration of language with thinking, valuing, acting, and interacting in the *right* places and at the *right* times with the *right* objects" (p. 13). It is my goal to focus on the socially accepted *rightness* of Discourse and the implicit construction of what is right or *whose Discourse counts?* The *right* Discourse is determined by matters relating to power; do the dominant recognize the speech acts and behaviors of the non-dominant as examples that warrant membership into a particular community or social network? The non-dominant positioning of children from communities of color throughout historical development of theories of learning (further analyzed in Section 4) introduce the need to examine the racialized power within Discourse. Gee's (1999) use of the word *right* positions Discourse as having a number of possible choices and variations, but also emphasizes that only a select few types or kinds of Discourses are recognized as socially suitable for particular occasions by participants. This process of sanctioning maintains a dominant standard of what constitutes an acceptable Discourse and legitimates a limited view of 'correct' Discourse. Thus, this limited view places at a disadvantage the Discursive practices of marginalized youth.

Viewing Discourse as a "standardized" or sanctioned way of engaging in an activity can actually be useful when viewed from one point of view. A common Discourse can provide continuity and efficiency within a group or community of people engaged in particular activities. For example, Brown (2005) discusses the acquired Discursive practices of individuals engaged in the sport of American football. American football players are acclimated to Discursive practices that include hand signals and gestures used to call plays on the field or invented language to specify the intended play (i.e., "4-3" is a defensive call where 4 lineman and 3 linebackers are to align in specific defensive positions). In this view, the hand signals and gestures used by American football players operate almost as technical language, allowing the players to communicate with precision and intention.

Discourses can become a “problem,” however, when they develop into sets of normative practices and behaviors that society and societal institutions, such as schools and the educational research community, use as tools for exerting social power and control, especially over marginalized communities. In these cases, the practices and talk shared by a community are used to demarcate ‘insiders’ from ‘outsiders.’

In essence, Discourse is not the source of the exclusionary practices within science education and science education research, but it is the vehicle through which ostracizing is made possible. It is how these Discursive practices are used that becomes problematic, when groups of learners are marginalized due to their non-membership in a particular community or group. This is important to note because a person’s acquisition of specific Discursive practices does not require delineation between ‘insiders’ and ‘outsiders.’ On the contrary, Discursive acquisition can and should be an inviting opportunity and positive experience for those choosing to participate in the activity.

Nasir (2005) illustrates how communities can interpret, use, and positively acclimate new members to engage in specific Discursive practices. She finds that children become accustomed to the cognitive and mathematical Discursive demands of playing dominoes by engaging in the activity with individuals who are more familiar with, even expert in, the expected Discourse. Communities and academic disciplines should recognize that individuals demonstrate a variety of Discursive practices and behaviors that add to the richness exhibited by the current Discourse. These new practices add to the community's ability to communicate and live effectively. Viewing Discourse as a dynamic or ever-evolving entity, that still maintains its purpose of community building, provides an inviting environment where individuals can acquire and contribute to the identity of a specified discipline. These two examples of Discourse acquisition are useful to keep in mind when thinking about how Discourse is positively interpreted and utilized. Despite the established Discursive practices that American football and dominoes have formed, both activities are continually evolving with the inclusion of new ideas, experiential knowledge, and alternative ways of thinking. Despite the inherent power structures that exist acquiring a Discourse within these two examples, I would argue that it does not dominate the relationship. Science Discursive practices, on the other hand, are considered by many, as removed from the everyday lives, languages, and practices of many children and they do not have to be that way. The literature suggests that the maintenance of limiting Discursive practices marginalizes many youth, as well as restricts the growth of scientific knowledge by delimiting potential ideas.

2.1 What are big "D" Discourse and little "d" Discourse?

The conceptualization of "big D" Discourse as socially situated provides an important distinction with "little d" discourse, which is most commonly defined as dialogue, conversation, and stories. Crawford, Kelly, and Brown (2000) found that a teacher's acceptance and recognition of the various kinds of Discourses present in the classroom promoted a thorough and creative class analysis of an elementary school marine biology unit. The concept of inviting a variety of Discourses into the unit created opportunities for student engagement in scientific discussion, cultivated students' personal interests in science, and introduced the class to alternate perspectives and approaches to doing science. After a student claim concerning the positioning of an aquatic plant in relation to a snail within a small classroom aquarium, the teacher facilitated a discussion that validated every student's use of claim and evidence, even if some of these uses conflicted with 'normal scientific reasoning.' In this instance, the classroom teacher recognized the non-dominant, scientific thinking of this child and allowed for the co-construction of *right* Discursive practices.

One student entered the discussion by stating that the aquatic plant was growing on the shell of the snail because the aquatic plant "thought" that the snail's shell was a rock. The student's claim was based on his prior knowledge of this particular plant's preference for clinging and growing on rocks and a brief three-minute observational period of the tank. Not only did this student utilize his previous understanding and knowledge of this plant, he also approached the situation from an atypical perspective; one in which he assigned the human qualities of 'thought and preference' to the aquatic plants. The teacher was able to recognize the scientific value in his claim and approach to the science discussion.

In contrast, Gee, Michaels, and O'Connor (1992) discuss the Discourse of "sharing time" to illustrate the conceptualization of Discourse within classrooms. The researchers reported that the first grade teacher they observed had a preconceived idea of what constituted the *right* kind of sharing time narrative that included a limited and strict set of elements. An African American student, familiar with the storytelling practices used by her family and community, was reprimanded for an 'unsuccessful' turn during sharing time because her performance did not follow the script expected by her teacher.

The researchers point out that this student's Discursive practices, in a different social activity, would have been highly valued by many mainstream cultures, thus creating the confusion that many children have with *what counts as the right* Discursive practices. This situation presented the teacher with the opportunity to explicitly support the student's acquisition of the *expected* (i.e., "right") storytelling Discourse for this situation. In contrast, this young child's elaborative and embellished storytelling was viewed as a demonstration of her deficiency in acquiring a "sharing time" Discourse appropriate for this classroom.

This rejection of the student's rich and varied Discursive practices by the teacher can also be referred to as a rejection of her cultural capital (Bordieu & Passerson, 1973; Giroux, 1983; Yosso, 2005). Cultural capital refers to the set of race, class, and gender linguistic and cultural competencies (e.g., what they know and how to do it) that children learn within their families and communities. Children learn whole sets of meanings, qualities of styles, modes of thinking, and types of dispositions that are given certain social value and status as a result of what the dominant class recognizes in their families and communities and labels as the most or least valued cultural capital (Giroux, 1983). Typically, the knowledge practices afforded the most cultural capital are those that are associated with the dominant class in the United States: white middle to upper-class individuals from European American descent.

In her study of the cultural capital in three communities in Piedmont, North Carolina, Heath (1983) examined the linguistic disconnect between households, community, and school. She observed that the Discursive practices of the upper and middle class communities were given the highest cultural capital value within the school community. In this review, I am arguing that the research base should be extended to include the implicit and explicit roles of social class, race, and institutionalized racism to understand the experiences of marginalized youth in science learning.

This review adheres to a functionalist perspective (Schiffrin, 1994) of Discourse that views language use as a social practice that is important when examining the role of Discourse in the lives of marginalized youth (Fairclough, 1989). Conceptualizing Discourse as a social practice is conducive to examining the experiences of marginalized youth in science learning because, as Gee (1999) states:

> the fact that people have differential access to different identities and activities, connected to different sorts of status and social good, is a root source of inequality in society. Intervening in such matters can be a contribution to social justice. Since different identities and activities are enacted in and through language, the study of language is integrally connected to matters of equity and justice. (p. 13)

This concept speaks directly to investigations of whose cultural capital is accepted in school and how we, as science education researchers, can begin to conceptualize the rich variations in Discourse that students bring to school as contributing to new understandings of learning and knowledge. Discursive studies involve examining youth's sociocultural, political, and mental lives and providing a perspective into marginalized youth's experiences with science and engineering that are otherwise obscured (Gee et al., 1992).

2.2 What *Counts* as Everyday and Scientific Discourses?

School science tends to privilege specific Discourses that are considered appropriate for participation in the scientific and technological communities. The advantages afforded to students who utilize these sanctioned Discursive practices (e.g., being recognized as scientific, increased identification with scientific careers, being recommended for higher–level science courses) illustrate the distinctions that result from being recognized as everyday or scientific in school science. Lemke (1990) describes the Discourses that are most valued in school science as avoiding emotional and value-laden practices, the use of stories and narratives, and communicating through slang. Ballenger (1997) further specifies additional characteristics of school science as featuring impersonal and explanatory experiences. The questions that remain in this section are: are students who engage in everyday Discursive practices really 'unscientific?' Are students who are labeled as 'unscientific' actually engaging in 'scientific' activity and thinking, but have not had explicit support or access to recognized Discursive behaviors? If we modified our definitions of what counts as scientific Discourse, would these once marginalized students be suddenly considered "right" and "scientific"? This helps to place the cause of the problems not on some deficit to be found within the students, but in the limitations of our understanding of scientific. The following segments will examine these questions through two Discursive practices that are typically classified as everyday: the use of imagination to include self into the scientific phenomenon and the use of narratives or stories to exemplify science knowledge.

2.3 Is the use of imagination a scientific Discursive practice?

Typically, science is considered an objective practice that values reasoning and abstract thinking while investigating and communicating scientific phenomena (Ochs, Gonzales, & Jacoby, 1996). Included in the list of unscientific, or everyday, practices are the act of imagining oneself within a physical phenomenon. Despite this distinction, scholars have identified instances where the use of imagination has been used to demonstrate scientific understanding and facilitate future investigations of a phenomenon. For example, Ogonowski (2008) examines the question, "is there a place for imagination in the science classroom?" (p. 31) Ogonowski describes an elementary school bilingual student who 'transformed' himself into a plant during a class discussion of "do plants grow everyday?" The student used a different entry-point in his investigation of the phenomenon by imagining his body as a plant. Typically, his actions in the classroom were considered "silly, off-topic, or unscientific" (p. 32) because of the passionate and subjective perspective they embodied, despite his ability to engage in the intended scientific conversation. Do the imaginary perspective and the subsequent engagement in an in-depth classroom discussion validate a label of everyday or scientific? In a similar study, Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) witnessed the 'scientific' value of using imagination to explore science phenomena. They viewed an elementary school Latino student examine the behavioral ecology of ants by imagining himself as an ant. Based on entry-point and use of imagination, the student was able to explore and devise an experiment that would examine whether ants prefer dark or light habitats.

Ballenger (1997) observed students participate in a science discussion on mold growth. One Haitian female middle school student, refuting a statement that mold grows in all bathrooms, exemplified her knowledge of mold growth, while implicitly stating that she knows how to clean and avoid the growth of mold.

> "Because they just leave stuff there, take no care, they don't clean, they just {} if you have a toilet in Haiti, you take care of it, it won't have mould. (p. 5)

Although her statement could easily be classified as everyday, based on the above categories, she also demonstrated a deep understanding of bacteria growth. Viewing these students as 'unscientific' is clearly a demonstration of the power relations that exist within recognizing Discursive practices because similar practices and behaviors have been witnessed among practicing physicists (Ochs, Gonzales, & Jacoby, 1996). During an ethnographic study on the Discursive practices of scientists, the researchers observed physicists interchangeably constructing "physicist-centered" accounts of a scientific phenomena and other, more formal scientific accounts that refrained from the "physicists-centered" approach (p. 335). Thus, it appears that students typically classified as 'unscientific' because of their initial practices in the exploration of science phenomena were actually engaged in Discursive behaviors similar to those of professional scientists.

2.4 Can the use of narratives and storytelling be scientific?

Another element of everyday Discourse in science classrooms is the utilization of narratives or storytelling in exploring science phenomena. The inclusion of narratives and stories are considered concrete and contextualized views of science that often involve emotions and personalization of ideas (Ballenger, 1997; Warren et al., 2005). Again, do students' use of narratives or stories classify them as unscientific? In a study exploring how young children used their everyday experiences to understand force and motion, Warren et al. (2005) observed how an elementary school African American girl created a story of a baby carriage on a hill in order to explore the idea of Newton's Laws of Motion. Despite the use of a "concrete" example of a baby carriage, this student engaged in a dynamic discussion of this carriage with her partner to explore the tendency of the carriage to roll down the hill [due to gravity] and how they would need brakes in order to stop its motion [Newton's Third Law]. The girl was engaged in scientific thinking that was not expressed in the recognized Discourse of school science. Warren et al. (2005) report that after presenting this student's story, many people view her as "going outside the boundaries of the task" (p. 143) and demonstrating a deficit in scientific abstraction. In contrast, I would argue against a deficit view of this student's scientific abstraction. First, she conceptualized the ideas of Newton's Laws of Motion and related them to her lived experiences. Secondly, this way of thinking was instrumental in her learning and using scientific language (e.g., the nominalization of a "turned car") and her discussion of the baby carriage's trip down the hill in the terms of change over time. In a separate study exploring students' language use during science discussions, Ballenger (1997) witnessed a Haitian middle school student narrate a story of his father mistakenly leaving food out and how he observed the growth of mold from oatmeal. Again, this student's story of the oatmeal and mold is a new entry-point[6] into investigating the idea or 'claim' that mold grows from old food. The classroom teacher used this student's narrative to

[6] The term entry-point is utilized in order to denote a student's initial attempt of making sense of specific science phenomena (Rosebery, Warren, & Conant, 1992). I think the use of 'entry-point' is significant because it implies that students use their initial conception of a science concept as a foundation to build upon, and develop deeper understanding of doing and talking science as they further engage with the phenomenon.

facilitate the explicit use of science Discursive practices by asking clarifying questions that prompted further discussion. For example, by asking the student where mould comes from, the teacher elicits the explicit answer of "from food" (p. 9) that begins a focused discussion on how science is involved in the experience.

Investigating how an inner-city science lunch group provided African American male teens the opportunity to participate in science in alternate ways, Seiler (2001) explored the scientific phenomenon of pitch with a group of African American high school male students during a science lunch group. As an entry-point into a conversation about why sounds have high and low pitches, one student provided the following story:

> It's the same way at my job, right? When I'm cuttin' hair, if the clippers don't sound a certain way, I take a screwdriver and twist the screw in the side. Somethin' getting loose. So, if it gets low and slower or increase the sound and become faster. (p. 1008)

As a way of demonstrating his experiential knowledge on the concept of pitch, this student provided a narrative of his experiences with clippers. Again, each of these students' Discursive practices would be classified as 'unscientific,' or "everyday", despite their underlying exploration of science concepts. Fortunately, the researcher in this study was investigating alternative Discursive practices in science and recognized the valuable contribution of this student to the success of the science lunch group. In an ethnographic study, Lloyd (2000) observed similar Discursive practices from practicing engineers. He suggests that the social experiences used in the engineering design process were communicated through storytelling. Storytelling appeared to be a central mechanism in developing the common language used in a design team. Using the above examples as evidence, the use of narratives and stories can serve as valuable tools for exploring science phenomena in the science classroom.

2.5 Summary

This section has explored how Discourse has been conceptualized and defined in previous literature and how which Discursive practices *count* is determined. Do students who do not use or have access to such Discursive practices automatically qualify as *unscientific?* The exploration into the use of imagination and narratives in elementary school science classrooms illustrates that children typically labeled as *unscientific* are often thinking scientifically. The means they are using to convey their scientific thinking may not be the typical or expected, however. The sanctioning of *what counts* as scientific Discourse can be utilized in limiting ways that create unnecessary barriers for children's development in science education. For example, Michaels and Sohmer (2000) reevaluated conclusions described by Michaels in a previously published study. In her initial study, Michaels concluded that one out of four students appeared more scientific than the others based on his language use. Although each of the middle school students provided 'incorrect' conclusion about the reason for the four seasons, one student was described as *sounding* scientific because of his school-based conversation style. The three students identified as *unscientific* were said to reason with "narratives of personal experience, blending discourse worlds (the life world with the school-based world), as magical, teleological, confused, and/or hard to understand" (p. 277). Upon further analysis of this group of students, Michaels and Sohmer (2000) found that the three *unscientific* students actually possessed a greater knowledge of the science phenomenon, but lacked access to the sanctioned Discourse. The researchers concluded that 'doing school science' is much more than simply talking scientifically and much more than a "matter of excluding yourself, your experience, or your body from the explanation" (p. 284).

In another study that calls for redefining standard methods for evaluating children's scientific thinking, May, Hammer, and Roy (2006) suggest that elementary school science needs to recognize the alternative scientific abilities of children and support them in their development as they acquire scientific Discursive behaviors. They highlight an elementary school student's use of analogy in explaining the cause of earthquakes:

> You know how to fill your water up and you put like too many ice cubes in it, it can flood? That's what I mean… a rock could go in, and pretend like, pretend the lava is water and the giant rock is a cube. It goes up and since it's blocked, the ground has to shake which causes it to crack open so it'll actually like go up farther. So it's like you're actually flooding the cup of the water. (p. 317)

Although the student's overall conceptions on the cause of earthquakes are misguided, he demonstrates a keen ability to think scientifically and attempts to make connections between the world of science and his everyday world. May et al. (2006) suggest that a typical science teacher would focus on his incorrect idea of earthquakes and miss the opportunity to introduce the sanctioned Discursive practices *and* to address his understanding of earthquakes. This discussion highlights the sometimes-cloudy distinction between *everyday and scientific* and how this dichotomy could, at times, lead to the continued ostracizing of large groups of students. Recognition of the Discursive practices that students bring to school can lead to a deeper understanding of the scientific phenomenon at the same time that it supports the acquisition of the Discursive practices valued in school.

3.0 CONCEPTUALIZING ENGINEERING DESIGN DISCOURSE

Teaching science through activities that emphasize engineering design and technology[7] has been advocated as a means of promoting science learning for all students (Seiler, Tobin, & Sokolic, 2001). Involving students in design activities is a major strand in the science and technology standards (AAAS, 1993; NRC; 1996) and is gaining recognition within the science education research community (Fortus et al., 2004; Klahr, Triona, & Williams, 2007; Penner, Giles, Lehrer, & Schauble, 1997; Puntambekar & Kolodner, 2005; Roth, 1996a). With the growing popularity of this pedagogical approach for the teaching of science, this discussion of Discourse has provided a theoretical foundation for reviewing the practices and behaviors that children from communities of color bring to these classroom environments. According to Dym (1994), engineering design is the "systematic, intelligent generation and evaluation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints" (p. 17). Activities involving engineering design have specific Discursive demands that differ from those needed in other disciplines, such as language arts, history, mathematics, and in some instances, science. This distinction is important because it illustrates the need for students to learn and properly utilize specific Discursive practices for different school subject areas. This is to say that the Discursive expectations of

[7] Technology refers to how people modify the natural world to address a specific problem (process) *and* the objects created during this process (product) (Leonard, 2004).

children and on children will vary, depending upon the activity that they are engaged in. For example, Discursive practices differ for students when they are in a language arts classroom versus a physics classroom (e.g., Moje et al., 2001). How a student conceptualizes Shakespeare versus gravitational force, uses literary versus scientific evidence, and communicates knowledge of a poetic verse versus knowledge of centripetal force exemplify the differences between language arts and physics classrooms. The intersections of varying Discourses, such as children's everyday Discursive practices and subject area Discourses, in the elementary school science classroom provides another important opportunity for the examination of the experiences of marginalized children. The goal of this section is investigate the Discursive practices that marginalized youth will face while they participate in engineering design activities.

I have chosen to specifically focus on engineering design activities because many scholars argue that all students will best learn science through engineering design and technology activities (Roth, 1996a, 1996b, 1996c; Seiler et al., 2001). Advocates for design-based classrooms suggest that the classroom Discursive practices and values in these settings resemble those found in out-of-school settings (Roth, 1996a, 1996b). This suggests that engineering design activities invite the use, investigation, and analysis of children's everyday ways of doing, knowing, and thinking with science and design content. Despite this implicit encouragement for the inclusion of varying demonstrations of everyday Discourses, questions still remain about how students' everyday Discursive practices can be incorporated into science learning through engineering design activities. Furthermore, although a commitment to improving science learning for all students is highlighted in national science standards (AAAS, 1993; NRC, 1996), it is not clear how the shift to incorporating engineering design into science classrooms will affect the learning outcomes and experiences of children from communities of color. Using engineering design activities to learn science creates a new arrangement of Discursive demands for all children. These new arrangements include the role that the designed artifact plays in science learning and the interpretation and utilization of the engineering design process. The remainder of this section examines empirical studies on elementary and middle school students[8] engagement in design opportunities[9] to address these new arrangements, and identifies and examines the Discursive demands that are distinctive to engineering design activities in science classrooms.

3.1 How does the design artifact introduce additional Discursive practices?

Design-based science is a pedagogical approach in which the goal of designing an artifact[10] situates students' learning experiences within engineering design activities. This construction of the designed artifact serves several important roles in engineering design Discourse acquisition. First, how the artifact is conceptualized and utilized during phases of design, construction, and analysis serve as vital components in the construction of children's knowledge. Using artifacts to construct valuable contexts that allow for the

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[8] In the typical United States school system, elementary and middle school includes students between the ages of 6 – 13.

[9] In conducting research with children who have often been excluded from engagement in academic Discourse and success, it is important to note that, historically, design was often reserved for the 'elite' who had the money to "afford such frivolous activity and the time to enjoy it (Pink, 2005, p. 75).

[10] Within design-based science, design artifacts are tangible, student-constructed products that are created to address a specific design challenge or problem (Fortus et al., 2005; Roth, 1996a). The process of designing and building such an artifact is conceived of as an engineering design process (Kolodner, Camp, Crismond, Fasse, Gray, & Holbrook, 2003; Krajcik & Blumenfeld, 2006), and these processes, as well as the completed 3D constructions, serve as an external representation of students' knowledge (Fortus et al., 2005; Uttal, 2000; Roth, 1996a; Vosniadou, Skopeliti, & Ikospentaki, 2005).

learning of science concepts has been effective in elementary and middle school classrooms (Penner, Giles, Lehrer, & Schauble, 1997; Roth, 1996a, 1996b, 1996c). Using this approach, designing, constructing, testing, and modifying an artifact facilitates the construction of knowledge that children are expected to acquire. This stands in contrast to a view of the artifact as an instantiation of students' previously acquired knowledge. For example, in a study by Penner and her colleagues (Penner et al., 1997, 1998), students initially used their everyday conceptions of how an elbow functions in order to create models that represented their ideas. Students initially had difficulty accurately representing the function of the elbow and its adjoining joints because they primarily focused on the aesthetic qualities of the elbow, rather than on the qualities of function. Students' iterative construction of the designed artifact facilitated their continued investigation into, and subsequent learning of, a more realistic view of the biomechanics of the human elbow.

Designed artifacts also serve an important role in the social construction of knowledge, as students formulate engineering knowledge in order to create models (Roth, 1996b). In these contexts, elementary school students develop an engineering design "language-in-use" (Roth, 1996b, p. 107), as opposed to mimicking teacher-framed definitions which, according to Roth (1996b), encourage students to make meaningful connections to science concepts. Roth observed a group of students initiate the use of "X-shape" as a description of the cross-bracing on their designed sturdy towers and develop a language that assisted them in discussing the stability and strength that these pieces added to the tower. Although "X-shape" is neither a typical or technical term used to describe these physical elements, like Roth, I suggest that this invented term provided the teacher with a meaningful entry-point into students' acquisition of specialized language. Thus, the designed artifact provides opportunities to foster student knowledge construction.

In addition to serving as a scaffold in students' knowledge construction, designed artifacts can also take the role of the product of student acquired knowledge throughout the design process. In a study by Klahr et al. (2007), for instance, middle school students represented their knowledge of various physics concepts through the design and construction of mousetrap cars. These students utilized physical and/or virtual artifacts to demonstrate what they had learned. The cars were tested against the constraints set out at the beginning of the process and the results of the testing were a concrete example of the students' development of the physics ideas.

In another study, a group of students constructed model bridges to represent what they had learned about physical concepts: tension, compression, shearing, and torsion (Sadler, Coyle, & Schwartz, 2000). Students' bridges were tested by applying weight until, at least one section failed due to applied pressure. Again, students' understandings of science were displayed *through* the designed artifact.

These examples of the designed artifact as a product can be conceptualized as emerging from a "heterogeneous assemblage" (Roth, 1996a, p. 141) of children's ideas from a situated activity "rather than the homogeneous fixations of children's ideas and skills" (p. 141). Viewing the "product" from this perspective, as situated within the activity and conceptualized differently by different children, positions it as a Discursive demand for children engaged in the activity of design. For example, engineering design problems are said to be open-ended (Roth, 1996a, 1996b), which implies that there is more than one acceptable solution. Thus, children are required to translate and clarify the design problem in order to construct a “product” that represents the intended science concepts and meets the predetermined design constraints.

3.2 How does the engineering design process introduce additional Discursive practices?

Discussion of the role of the designed artifact introduces another Discursive demand of the activity of design: the interpretation and navigation of the engineering design process itself. The engineering design process entails using science and mathematics knowledge to create solutions to human problems (Cross, 2000; Dym, 1994). Typical human problems or “real-world problems are ill-defined to some degree, lacking required information and not having a well-defined ending state – and therefore with neither a known correct or best solution” (Fortus et al., 2005, p. 855). The engineering design problems presented to elementary and middle school students often incorporate these qualities and thus are analogous to real-world problems in many ways (Roth, 1996a, 1996b; Sadler et al., 2000). To assist students in tackling such problems, student engineering design activities are typically organized around a formal, iterative, somewhat static decision-making process (Figure 1). I argue that students’ use of this design process introduces additional Discursive demands, despite its intention of providing clarity and support.

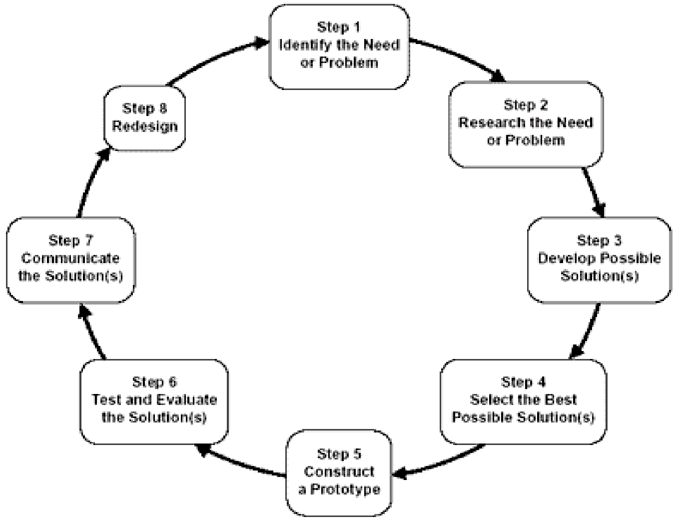

Figure 1: Steps of the Engineering Design Process (Massachusetts Department of Education, 2001

Literature focusing on students' interactions with the engineering design process (Fortus et al., 2004, 2005; Puntambekar & Kolodner, 2005; Roth, 1996a, 1996b, 1996c) is primarily interested in children's cognitive development within specific science content. Although the conclusions from these studies discuss the cognitive impact on children of learning in design based classrooms, I suggest that student navigation through the design process itself should also be an important focus of analysis. Elementary and middle school students' navigation through the 'formal' steps in the engineering design process (Figure 1) is a Discursive demand that is unique to school-based design activities. The design process is presented as a linear and procedural process (Fortus et al., 2005). Analysis of the illustration suggests that step 2 will always follow step 1, that step 3 will always follow step 2, that step 4 will always follow step 3, and the remaining steps will continue in a similar pattern. Despite this depiction of the process often presented to students, several variations of the engineering design process exist and depend on a specific area of engineering (Cross, 2000) and the developmental level of those utilizing the process (Fortus et al., 2004). Several of these variations depict the structured steps of the engineering design process as being executed "out-of-order." Figure 2 is an example of a revised, cyclic design process that is sometimes utilized in some middle school classrooms that utilize engineering design (Fortus et al., 2004). This view reduces the number of 'formal' steps and presents the engineering design process as more dynamic and interactive than the process represented in Figure 1. The formal, rigid, and predictable design process in Figure 1 is replaced with the less formal, more responsive, and fluid process in Figure 2.

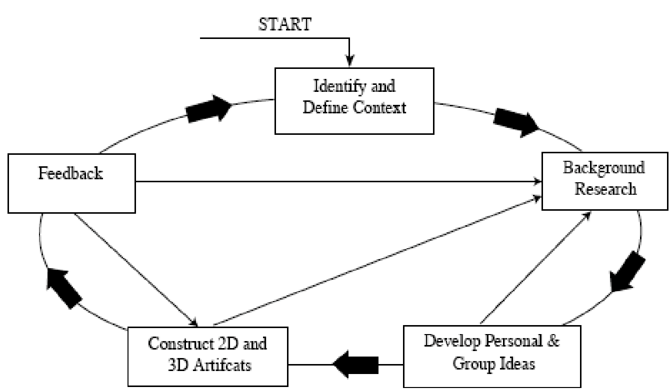

Figure 2: The Revised Engineering-Design Process (Fortus et al., 2004)

3.3 Discourse and children's interpretation of the engineering design process

My belief that Figure 2 represents a more realistic depiction of the engineering design process originates from assessing its similarities to other engineering design processes utilized by professional engineers (Cross, 2000; Dym, 1996; Layton, 1993). Despite my belief in this process, students are faced with a wide range of value judgments and decisions about what constitutes 'appropriate' design. For example, at the "developing personal and group ideas step," (as shown in Figure 2) students are faced with the decision of continuing with the process of constructing a design artifact or developing more ideas by conducting additional "background research." The demand on decision-making is further complicated when students arrive at the "feedback step" (as shown in Figure 2). At this point, students can: a) decide that their design process is complete (this 'step' is not depicted in Figure 2, but would be positioned between 'feedback' and 'identify and define context'), b) decide to conduct more background research and go through the entire design process again, or c) make adjustments and corrections to the design artifact that may increase its performance or better represent the students' science knowledge (this step is depicted as 'construct 2D and 3D artifacts in Figure 2). According to best practices, students should modify and test their design often, possibly on a daily basis (Sadler, Coyle, & Schwartz, 2000). This regular and consistent testing and modification requires students to make a decision about moving forward with the current design, making minor adjustments or completely starting anew. The level of reflection, evaluation, and interpretation expected from children is quite extensive. Dym (1994) uses the problem of designing a 'safe ladder' to discuss the difficulties in interpreting the design process. He contends that varying interpretations of each of the following kinds of questions present challenges to students: "What does it mean for a ladder to be safe? That it should not tip on level ground? That it should not tip on a mild slope? How much weight should a safe ladder support?" (p. 1). Students' interpretations of these questions, and of other questions involved in the process, provide opportunities for different designs. Students are expected to utilize this iterative reasoning design process to produce an artifact that creatively represents their science knowledge. In addition to the expectation of designing a creative artifact, students are also expected to continuously develop their current science understanding, thus constructing an additional Discursive demand for the student.

The interpretation of the engineering design process also introduces the Discursive demand of evaluating and assessing a "final" design and the techniques used to complete their artifact. Some rather impressive metacognitive thinking is expected from students as they are required to reflect on previous results, maintain accurate record keeping (Puntambekar & Kolodner, 2005; Sadler et al., 2000), and determine how their solution will address the proposed problem (Fortus et al., 2005). Middle school students have been identified as needing multiple forms of support to meet these demands in maintaining data; for example, they need support such as "design diaries" which have been used to do this with some success (Puntambekar & Kolodner, 2005). Design diaries allow students to record their thinking processes, as well as the results of their analyses for later use and interpretation. Some middle school students have also utilized computer-based "design discussion areas" (Kolodner & Nagel, 1999) that allow students to provide consistent thinking processes and retrieve feedback throughout the entire design process. The ongoing metacognitive analysis proves valuable when students are required to make decisions and present their final interpretations. Other classrooms have simply utilized consistent classroom or group discussions of constructed models as a tool for evaluation (Penner et al., 1998).

Differences that exist in students' approaches to engineering design problems and their learning outcomes are affected by what Roth (1996a) calls, "interpretive flexibility" (p. 142). Since different students have different interpretations and meanings of the engineering design process, how they conceptualize the design plans, design artifacts, and design problems will vary amongst the students. “Interpretive flexibility” (p. 142) also extends to the tools, materials, and resources that students use during the design of an artifact.

Although students typically draw on knowledge and skills from a range of subject areas in developing their interpretation, they generally use science and/or mathematics (Fortus et al., 2005; Layton, 1993). While using everyday and school knowledge of science and mathematics to design and evaluate artifacts is a goal of design-based science, it also places a new Discursive demand on students that is unique to the design-based science classroom (Penner et al., 1998). In a study exploring students’ knowledge demonstration while engaged in hands-on and computerized virtual activities, middle school students were observed utilizing their everyday and school-based science knowledge to design physical and virtual mousetrap cars (Klahr et al., 2007). Students applied their knowledge of simple machines and levers to design several features of a car, such as the arm that transfers the energy from the mousetrap spring to the axle of the wheels. In addition, they had to apply their knowledge of friction, torque, and potential and kinetic energy to successfully complete the design task. During a design discussion, Penner et al. (1998) observed elementary school students determine the appropriate location of a model elbow and its connecting muscles and joints by applying data from a graph. The classroom teacher utilized data from students’ previous trial-and-error attempts in designing the elbow to inform a more ‘precise’ version of an elbow.

3.4 Summary

This section conceptualizes the Discursive demands presented for students in design-based science classrooms. A conceptualization of engineering design Discourses is important because of the increased interests in presenting science in these kinds of classroom environments (Fortus et al., 2004; Klahr, Triona, & Williams, 2007; Penner, Giles, Lehrer, & Schauble, 1997; Puntambekar & Kolodner, 2005; Roth, 1996a). I find it particularly important to highlight and discuss the Discursive demands placed on students that are typically marginalized in science classrooms (Brickhouse, 1994; Brickhouse et al., 2000; Brown, 2005; Seiler, 2001; Seiler et a., 2001).

The engineering design process and the artifacts produced during the design process introduce new Discursive demands and practices to elementary and middle school students. These new practices include the interpretation, appropriation, and navigation of the engineering design process and the different roles of the designed artifact – artifact as a product of knowledge and artifact as a process in developing knowledge – in this design process. I suggest that an analysis of the relationship between students' everyday Discourses and the academic Discourses presented by engineering design would provide a view into the complex experiences of elementary school students in design-based science classrooms. Roth (1996b) illustrates some of these experiences as he observes the 'engineering design language' that elementary school students appropriated and used to demonstrate what they had learned or their knowledge within an engineering design unit. The number of empirical investigations into children's experiences with varying Discourses in engineering design environments are limited and tend to focus on what students learned rather than how their knowledge developed throughout the process. The aforementioned studies highlight the knowledge and language that students are able to produce after participating in engineering design activities, but do not consider students' developmental process through these activities. In reviewing these empirical studies, I assert that an in-depth examination of students' experiences during design-based activities is necessary. Previous studies illustrate where students end up, but how they get to that point is under conceptualized. How and what students learn as they make sense of the Discursive demands within engineering design contexts are vital if we expect students to be successful in design-based science classrooms.

4.0 THE RACIALIZATION OF DISCOURSE

This section contributes to the primary issue of this review, *whose Discursive practices count,* by looking at the implicit and explicit relationship between past and current learning theories that have conceptualized children of color. Exploring the ways in which students of color have been positioned, and at times continue to be positioned, in theories of learning will assist in suggesting alternative methods for future investigations. This exploration will help us to understand how a racialized perspective on Discursive practices has developed and continues to be incorporated in current perceptions. Racialization is the social construction of a specific image, character, or context on groups of people, imposed specifically by racial characteristics[11] (Murji & Solomos, 2005). This imposition of racial character can be applied to people or to

[11] Although I am only looking at the imposition of race, I am not suggesting that acts of racial meaning-making agency, both collective and individual, are not equally significant.

actions, such as style of dress, educational experiences, and Discursive practices. Despite inherent intra- and inter-ethnic[12] group differences, researchers and historians have consistently essentialized[13] the Discursive practices of children from various ethnic groups (Nasir & Hand, 2006). Lee (1994, 1997), for example, finds that Asian American students are commonly depicted as exceptional "academic participants or model minorities" (p. 413). This stereotype reflects the belief that Asian American students are inherently successful in school, particularly in mathematics and science. Lee asserts that this reduction of all Asian American children into a single category virtually ignores the voices and experiences of numbers of Asian youth that attest otherwise, thus overlooking the variation that exits within this racial grouping.

Further analysis of this stereotype shows that it also affects the views of other racial groups that are considered "minority." By categorizing Asian Americans as a "model minority" and associating their perceived success with inherent traits, educational researchers and educators are implicitly suggesting that other minority groups are unsuccessful because they are inherently incapable of success or not dedicated to academic achievement. As Gee (1996) has argued, when a dominant ideology or Discourse retains the right to recognize and legitimate other Discourses, this establishes an ideal situation for one group to be negatively racialized while one group maintains dominance over others. The following sections discuss two ways that Discourse has been

[12] Ethnicity signifies shared cultural, linguistic, behavioral, or religious traits. Although race is often referred to as simply a socially constructed category that includes different phenotypes (Slaughter-Defoe, Nakagwa, Takanishi, & Johnson, 1990), it is important to include conceptualizations of race that discuss the historical realities of subordination and the racial self-awareness that is exhibited by varying groups of people (Gotanda, 1995).

[13] Essentializing can be described as the practice of collapsing individual differences into broad group characteristics that can explain assumed inherent, biological, and natural similarities (Nasir & Hand, 2006). This practice is often adopted by dominant ideology in order to promote stereotyping and inaccurate interpretations of individual differences.

conceptualized in education in the last century and how race and racism have informed the everyday lives and Discourse practices of students of color within urban settings in the United States (Lee, 2004).

4.1 Cultural Deficit Theory

Beginning in the late 1950's, the cultural deficit theory followed on the eels of the genetic deficit theory that believed that certain groups of people were intellectually inferior to other groups. The cultural deficit theory, thus, was simply a tool used to explain the inequalities in educational achievement between white, middle to upper class students and low-income students of color[14]. Cultural deficiency[15] was used to theorize that low-income students of color faced the difficult task of overcoming the environmental limitations and handicaps present in their families and communities (Banks, 1993; Friedman, 1967; McLoyd & Randolph, 1983), which included "substandard social behaviors, language practices, and attitudes toward scholastic achievement" (Gonzalez, 2008, p. 93). This theory solidified the foundation for devaluing the everyday contexts, communities, and Discursive practices of low-income students of color by deepening the belief that it was the role of formal, academic schooling to save these children from their everyday experiences (Banks, 1993). The Head Start preschool

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[14] While I recognize the fact that the cultural deficit theory was used to conceptualize the experiences of all low-income children, the focus of this review is how the theory was used to explain the experiences of children from communities of color. Recognizing that the theory originated for conceptualizing the experiences of children from low-income neighborhoods, I must provide statistics that legitimate my choice in privileging the study of students of color. In 1966, 65.3% of African American children were living below the poverty line, while 29.7% of European American children were living below the poverty line (U.S. Census Bureau, 2007). Thus, the disparity between children of color and European American children at that time highlights the center of interest for the theory.

[15] Cultural deficit and deficiency are used synonymously throughout this review.

programs, for example, aimed at combating the deficient Discourse that students brought to school, emerged from this belief (McLoyd & Randolph, 1983). From this perspective, the purpose of schooling was to eradicate students' "deficient" knowledge and Discursive practices and replace them with more 'culturally' and socially accepted practices. Persell (1981), for instance, expresses the view held by many white, middle-class educators of circumstances and the purpose of educating the Sioux Indian:

> The school gets this child from a conservative home, brought up speaking the Indian language, and all he knows is his Grandma. His home has no books, no magazines, radio, television, newspapers – it's empty! He comes to school and we have to teach him everything! … The Indian child has such a meager experience. (p. 25)

A cultural deficit theory allowed the mobilization of an entire collection of institutional and gate-keeping practices in school. By devaluing the Discursive practices that low-income students of color bring to school, scholars, in effect, maintained middle-class 'whiteness' (Lee, 2004) as the normative standard, thus reinforcing the foundation for the racialization of Discursive practices in educational research and educational practice. In addition, by classifying the Discursive practices of low-income students of color as deficient, scholars reduced them to single, identifiable traits, and succeeded in minimizing the possibility that other researchers might uncover the existing rich and creative variations within these communities. In the next section, I will show how this line of educational research appears currently in another form: a focus on "at-risk" children.

4.2 At-Risk Students

The cultural deficit theory has silently maintained its place within education research, surfacing currently under the theoretical perspective of research on "at-risk" children. Risk is a "construct used to designate a high probability of poor developmental or school outcomes" (Baker, 1999, p. 62). At-risk children are identified by community deficiencies (e.g., chronic poverty situation, bad neighborhoods, poor schools), family limitations (e.g., being minority, poor parenting skills, lack of structure and rules, "illiteracy," teenage parents), and demonstration of adverse behaviors (e.g., poor social skills and school performance) (Banks, 1993; Levin, 1989). Reinvented from its close relative, the cultural deficit model, the notion of "at-risk" youth continues to devalue the everyday contexts and Discursive practices of low-income students of color (Lee, 2003). I contend that the continued use of "at-risk" youths further ignores the fundamental role of societal institutions (e.g., schools, government agencies, prisons) as major contributors to placing communities "at risk."

4.3 Summary

By examining the historical conceptualizations of everyday Discourses of students of color, this section provided a theoretical foundation for investigating the question of *whose Discursive practices count*. While examining the historical perspective on this issue, this section has identified three commonalities: the essentializing of Discursive practices into traits that members of a group "carry with them from place to place" (Nasir & Hand, 2006, p. 450); the maintenance of middle-class 'whiteness' as the normative standard against which all students are assessed (Cammarota, 2004); and the failure to recognize alternative demonstration and embodiments of knowledge (Ladson-Billings, 2003; Miller-Jones, 1991). The use of the cultural deficit theory to explain the academic performance of students of color implied that these students lacked an important, meaningful, and intellectual culture. Although cultural deficiency is no longer explicitly used to explain the academic performance of children from communities of color, other terms such as "inner-city, at-risk," (Lee, 2003), and 'urban' have become code words for children who are not racially classified as white. These code words have contributed to the normalizing of Discursive practices of racial groups and exemplify the power of institutions (e.g., school and academic research) in creating, shaping, and regulating the identities of marginalized children (Ferguson, 2001).

I propose that science education research begin to position the Discursive practices of students of color as sources of knowledge, and not as deficient behavior that needs to be reprogrammed. The development of normative scientific Discursive practices can initially be examined through the empirical studies surrounding design-based science. Of the studies used to examine an engineering design Discourse for elementary and middle school students, not one includes, let alone focuses on, the experiences of children of color. Because of this exclusion of students of color from research that determines the effects of design-based science on student learning, the white, middle-class will continue to maintain its consistent reference point as a standard for determining and examining Discursive behaviors. My intention in analyzing these ideas is to illustrate how racial ideologies shape and constrain students' academic experiences and identities (Lee, 2004). In the next section, I will examine these constraints specifically in relation to the development of everyday and scientific Discourses.

5.0 DISCOURSE STUDIES IN SCIENCE EDUCATION RESEARCH

This section will now situate the issue of *whose Discursive practices count* within science education literature. Discourse studies have a historical presence in literacy studies (Gee, 1996; Heath, 1983; Ladson-Billings, 2005; Moll, 1992, 2005) and in recent years that presence has been extended to other academic disciplines as well. The extension of the study of Discourse into science education research is the focus of this section. Studies in the area of science Discourse can generally be divided into two traditions: a discontinuous and a continuous model. Followers of the discontinuous perspective, perhaps better known as the 'misconception tradition' in science education research,

> hold that students' everyday ideas are often wrong, strongly held, difficult to change, and interfere with learning. From a discontinuity point of view, the goal of education is to replace, repair, or fix students' wrong ideas and ways of knowing with correct ideas through a variety of instructional means. (Warren, Ogonowski, & Pothier, 2005, p. 120)

This view of students is ominously reminiscent of that held by the cultural deficit and 'at-risk' theories. I see a link between the discontinuous model, or misconceptions tradition, and the cultural deficit and at-risk perspectives because they all hold in common the belief that schools serve the purpose of eradicating 'deficient' students' previous everyday, community, and/or family-based knowledge and Discursive practices. In accordance with the discontinuous model, French and Peterson (in press) contend that many children living in poverty have limited exposure to academic language and discourse practices before they enter school, therefore, school programs that engage students in language practices experienced in middle-class homes are necessary. In spite of their claim that children should have access to the academic Discourses that are valued by schools, I argue that they do not value the *everyday* knowledge that children come to school with and view them as deficient and in need of further development. This privileging of certain Discourses is impossible to separate from the maintenance of racial hierarchy, particularly in and through schooling. Lee, Fradd, and Sutman (1995) state that, when compared to norms established within white, English speaking communities, students from communities of color[16] had more difficulty with science knowledge and vocabulary. I view these studies as situating the Discursive practices of students from communities of color within a deficit perspective. Instead of examining the Discursive practices exhibited by these students, the researchers positioned their practices against those demonstrated by white, middle-class, English students. This positioning maintains the limiting view on *what counts as sanctioned Discursive practices* and devalues alternate ways of demonstrating scientific knowledge.

With its use of language that invokes foundational ideas of the cultural deficit theory, a misconceptions or discontinuous tradition perpetuates the essentializing and racializing of science Discourse. I will discuss the effects of these two processes in unison because their development is simultaneous and co-constitutive. In the discontinuous tradition, Discursive practices used by marginalized students are seen as educationally irrelevant, and thus judged as deficient when compared to those of mainstream students.

[16] For this study, students from communities of color included African American students, bilingual Spanish students, and bilingual Haitian Creole students (Lee, Fradd, & Sutman, 1995).

Further, research in this tradition has sometimes essentialized the practices and behaviors of students of color into single identifiable traits. Lee, Fradd, and Sutman (1995), for example, investigated the accuracy of science knowledge and use of scientific vocabulary differences among monolingual English-speaking white students, African American students, bilingual Spanish speaking students, and bilingual Haitian students. The following excerpt was provided by a group of students within the white, middle-class, English-speaking students as an example of students' accuracy of science knowledge and use of scientific vocabulary:

> Boy 1: A person is driving down the road, and he sees this big rock, this little rock, and a board.
>
> Boy 2: Then he gets out of his car and starts looking around.
>
> Boy 1: So he makes a lever, puts a fulcrum and the load.
>
> Boy 2: Put the fulcrum closer to the load and farther from your force.
>
> Boy 1: And then he moves it and drives away. (Lee, Fradd, & Sutman, 1995, p. 805)

The students' ability to utilize the academic Discourse necessary for school science success is quite evident in the example. In contrast, the next excerpt was provided by a group of bilingual Haitian Creole boys for the same task as described above:

> A man travels along. He sees the big rock, a little rock, and a stick had fallen on the road. He looks at it to see if he could figure out where to move the big rock and all the other things. So he gets out of the car and puts the little rock under the stick close to the big rock. He pushed down the other end and moves the big rock

upward and back around. The rock moved out of the way, then he drove by. (Lee, Fradd, & Sutman, 1995, p. 806)

This explanation is described as 'reasonable' (Lee, Fradd, & Sutman, 1995, p. 806), lacking the scientific precision and use of academic language when compared to the first group of students. Notable in this description is the phrase "when compared to the first group of students." The comparison of the explanations of students of color to the explanations of white, English-speaking students situates the Discursive practices of white, English-speaking students as the norm against which all students are measured. I contend that the Haitian students' 'reasonable' explanation should be viewed as a demonstration of scientific knowledge and used as a foundation for future development in science understanding. The continued comparison of the knowledge demonstrated by students of color and middle-class, white students positions students of color as the "other" (Lee, 1994) and as scientific "outsiders" (Brickhouse, 1994).

In contrast to the discontinuous model, a second tradition of research exists that views students' language and science Discourses as continuous with one another. The continuous tradition,

> focuses on understanding the productive conceptual, metarepresentational, linguistic, experiential, and epistemological resources students have for advancing their understanding of scientific ideas. (Warren et al., 2001, p. 531)

This tradition of research posits that scholars examine the varying intra- and inter-group Discourses that students bring to school and investigate ways of building upon this understanding. Hudicourt-Barnes (2003), for instance, found that Haitian students actively engaged in scientific argumentation when a cultural practice of *bay odyans* was recognized as legitimate within the science classroom. *Bay odyans* is an oral literary genre unique to Haiti. It is defined as a form of "chatting" that focuses on words or stories and often takes the form of storytelling, telling jokes, and riddles, or just reminiscing. This kind of talk sits in contrast with ways of demonstrating scientific knowledge and reasoning skills that are deemed 'scientific' or 'academic' (Lee & Fradd, 1995, 1998; Lee, Fradd, & Sutman, 1995). For example, one student, Steve, told his classmates that he had taken approximately 10 snails home and after three weeks possessed over 30 due to the original snails having babies. In order to challenge Steve's claim, Danielle says:

> You say you have 30 snails. How long does each snail take to have babies? Like, does a snail that is, if it is born today, could it make babies tomorrow? (Hudicourt-Barnes, 2003, p. 85)

Danielle is questioning Steve's claim of how long it takes for snails to grow, become sexually mature, and reproduce. The researchers posit that Danielle is asking Steve for specific evidence from snail development that would support his claim. In the form of a *bay odyan,* she is "basically saying to Steve that in science you cannot propose an observation that is inconsistent with other observations previously made unless you have strong evidence to support your claim" (Hudicourt-Barnes, 2003, p. 85). Again, despite the use of language that some would classify as unscientific, Danielle demonstrated her scientific thinking by challenging a claim that she felt was not backed up by sufficient evidence. By building upon this demonstrated knowledge, a science educator has the opportunity to provide Danielle the access to academic Discourses while validating her scientific knowledge.

In another study that focused on language use in science education, Gee and Clinton (2000) initially described a young, African American female student as not demonstrating the thinking and speech skills associated with school-based Discourses. While engaged in a conversation centered on a light box ad the way it reflected and refracted light, the elementary school students' science language was categorized as having narrative-like qualities and being "too-rooted in concrete events" (p. 121). A later review of the interview, however, led the researchers to develop a new perspective on their interaction with her. They came to view the student as having a "different entry-point" (p. 132) into the scientific world from the one they had expected. They concluded, in fact, that the student had a much deeper understanding of the topic than most students at her age. Upon reflection, they realized that their portrayal of the student's thinking and language were contingent upon their personal Discourse, as well as the assumptions and beliefs typically associated with school-based Discourse.

In their study of the everyday sense-making of science content, Warren et al. (2001) present a case that illustrates how students who demonstrate what would be considered to be atypical science Discursive practices are labeled as being 'unscientific.' For example, responding to the question, "why, if people eat and eat, don't they change their skin, don't they transform, the way insects do?" Jean-Charles responded:

> Manuelle, skin changes. It's like, the larva, when it was inside the egg, like when you were inside your mother's stomach. It's like, when you were a little baby, when you were born, when you were a little baby, you had hardly any hair. Didn't that change? Don't you have hair? (Warren et al., 2001, p. 536)

This student's broad use of the term 'change' initiated a classroom discussion that would typically be classified as unscientific because of the students' use of Haitian Creole (this was the first language of many of the students), jokes, references to religion, basketball, bathing, elderly people, and other physical demonstrations of the science phenomenon. The students in the class used ways of talking, making arguments, and developed theories (such as the one provided in the example) that would typically go unrecognized or devalued in a typical science classroom. Warren et al. (2001) show, however, that these students are actually demonstrating a different conceptualization process that is both complex and scientific when examined in detail. Again, I argue that these students should be positioned as scientifically literate and should be provided further access to the Discursive practices that are valued in school, while legitimating their current ways of knowing and making sense.

5.1 Summary

This section is not intended as an extensive review of the discontinuous and continuous traditions of science education research, but rather focuses on how these two traditions have informed the field's view of students of color. Despite the rich literature that exists on misconceptions (McCloskey, Caramazza, & Green, 1980; McDermott, Rosenquist, & van Zee, 1987) and the continuous tradition in education research (di Sessa, Hammer, Sherin, & Kolpakpwski, 1991; Minstrell, 1989) that look at students from dominant communities, I have focused on literature that was explicit in its focus on students who are typically positioned as outsiders (Brickhouse, 1994; Seiler, 2001) in the scientific community. I contend that the discontinuous tradition perpetuates conditions in which a mainstream, normative ideology can ostracize students who do not demonstrate these ‘expected’ Discourses. Studies that work within a continuous tradition contribute to the creation of a counter-argument, that is, they reassess aspects of a familiar story to form a different ending. Instead of adhering to deficit theories, these scholars focus on the knowledge and Discursive practices that children bring to their development in science, and use these strengths as the basis for successful teaching and learning. In this way, studies in the continuous tradition establish new opportunities for expanding the theoretical lens through which students’ Discursive practices can be viewed, analyzed, and discussed.

6.0 BROADER IMPLICATIONS AND FUTURE DIRECTIONS

In this review, I have sought to investigate the issue of “whose Discursive practices count.” In doing so, I have examined how everyday and scientific Discourses have been situated in previous science education research. How children demonstrate their science knowledge and how those practices are recognized and valued have been the focus of this review.

At the same time, I have attempted to illustrate how the recognition of “scientific” thinking, especially the thinking of marginalized children, is subjective in nature. I have attempted to introduce race as more than just a conceptualization of skin color and phenotype, and begin to illustrate “how ways of being, knowledge construction, power, and opportunity are constructed along and conflated with race” (Dixson &Rosseau, 2006, p. 48). Using this conceptualization to examine empirical studies in science education research, this review has illustrated how the Discursive practices of students of color have often been excluded or devalued and how the normalization of 'what counts' as scientific thinking is maintained through this process of excluding or devaluing. I argue that the future positioning of students of color in science education research, with respect to science Discourse, must recognize the 'voice' (Dixson & Rosseau, 2006; Ladson-Billings, 2005; Solórzano & Yosso, 2002) of these students and include their experiences in theories that account for the teaching and learning of science. With the increased recognition of design-based science as a pedagogical approach to teaching and learning science (Fortus et al., 2004; Klahr, Triona, & Williams, 2007; Penner, Giles, Lehrer, & Schauble, 1997; Puntambekar & Kolodner, 2005; Roth, 1996a) and the theories that will develop from the research, I suggest, as does Lee (2007), that we cannot understand the diversity in student development until there is significant research on diverse populations. In order to develop any comprehensive theories of learning within design-based science classrooms, all children need to be included in the conversation and research (Nasir et al., 2006).

Discourse as a set of socially accepted ways of believing, interacting, and thinking is a significant concept when examining the experiences of students of color. Children's epistemological beliefs are constructed, demonstrated, and evaluated through their Discursive practices. The conceptualization of Discourse as socially situated introduces the necessity for investigating all of the "social" Discourses encountered by children as they acquire and exemplify their knowledge. Examining marginalized students' ways of being, knowing, and learning should be viewed from the stability provided by historical and social factors, but also include the emergent qualities that have derived from these factors (Lee, 2007). This level of analysis reduces the opportunity of essentializing the practices of students of color into neatly defined traits and begins to position Discursive practices as cultural repertoires of practice (Gutiérrez & Rogoff, 2003). For example, investigating the ideas that marginalized children have, where they draw their experiences from, and how they impact learning during design-based science activities provides an in-depth picture of children's experiences and development in design-based science. Insisting on recognizing the experiential knowledge, or non-dominant Discourse, of people of color and their communities (Dixson & Rosseau, 2006) is core principal that I plan to continuing developing as I further investigate Critical Race Theory. Using this as a core principal for future studies, I plan to illustrate how by recognizing and valuing children's emerging Discourses can provide valuable contributions towards broadening the perspective on 'what counts' as scientific knowledge and behaviors. The 'voice' or stories of the experiences of marginalized children can be valid forms of evidence and ways to challenge the dominant discourse (Bell, 1992; Harris, 1995; Ladson-Billings, 2003; Ladson-Billings & Tate, 1995) within science education research.

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