IDENTIFYING BARRIERS AND BRIDGES IN DEVELOPING A SCIENCE IDENTITY

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ABSTRACT

This paper explores the variables that impede (barriers) and encourage (bridges) students to develop a science identity. The research critiqued suggests that by incorporating students non-science identities and previous life experiences into science curriculum, students are more likely to identify with science concepts. Also, this research shows that by addressing the nature of science identity barriers, educators can help create a conception of science that is inclusive of the beliefs and values of all students, increasing the likelihood that students will develop characteristics of a science identity.

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CHAPTER ONE: INTRODUCTION

In a science classroom most students do not connect with every learning experience they encounter during a typical class period. As an experiential science teacher in an outdoor setting and a pre-service classroom science teacher, I am especially concerned with how students become intrinsically engaged in learning science. In viewing learning as an identity-dependent endeavor, educators may work on how to make science relevant to students' individual lives. During my experience teaching ecology to middle school students in the redwood forests of California, the most challenging moments arose when certain students appeared to be disengaged and apathetic to the learning experiences. I was unable to facilitate science learning for all students, though I tried all of the techniques I was aware of to engage them. This included using multiple and varied activities to demonstrate one concept, cooperative activities, and many kinesthetic activities. At this time I viewed learning as occurring through wonder and curiosity, and I envisioned this happening through helping students see the complexity and beauty of our natural environment. While these methods worked for many students, other students did not buy in. My students were all diverse and unique individuals, but I made little attempt to acknowledge their existing identities and meet them where they viewed themselves.

This research revolves around how students of science develop a science identity. There are two primary questions investigating the relationship between science learning and a science identity:

1) What barriers prevent students from developing a science identity?

2) What pedagogical strategies can science educators use that will diminish barriers toward developing a science identity?

Rationale

It is necessary to begin this paper with a clear definition of what it means to possess a science identity. A science identity is a particular dimension of an individual's collective identity that allows the individual to intrinsically connect with science material, whether it be during an educative classroom process, engaging in science conversation, or watching a science film. A science identity enables an individual to connect science information and concepts to their lives, while also providing a lens for interpreting their everyday experiences and interactions within their worlds. If a student is to be successful in internalizing conceptual science understandings, he or she must be able establish a relationship with the curriculum as it connects with his or her identity.

Taking an identity approach to science learning begs the question: why is it that some students struggle to develop a science identity that would enable their science learning? To answer this question, educators must identify barriers that prevent the development and adoption of a science identity. In identifying the barriers that restrict, and in some cases repel students from developing a science identity, educators can reform their pedagogies to increase opportunities for students to recognize the intrinsic benefits of developing a science identity. By understanding how students are resistant towards science learning, educators can begin to integrate these resistances into their practice, acknowledging to students that their needs and challenges are being recognized and respected. Integrating resistance into the creation of positive learning activities is a way for teachers to collaborate with students and establish an empowering, democratic classroom.

To complement the identification of barriers explored in the previous question, this paper also seeks to identify specific means to which these barriers towards developing a science identity can be dissolved. To use Gee's (2007) terminology, 'bridges' represent methods that enable students to cross through barriers and establish a science identity. Due to the nature of both barriers and bridges being student specific, there is an emphasis for educators to practice flexibility and responsiveness to students' individual needs and demonstrate an ability to differentiate instruction.

Bridges most often involve meeting students where they already are, with an understanding of what Gee (2007) calls their 'real world' identities. Real world identities are heavily rooted in prior knowledge, experience and the perceptions of and interactions with the individual's various layers of community. While some students' real world identities might include a science identity, many students may only engage in science within a science classroom. It is these students that face the most challenges when learning and applying science.

Lave and Wenger (1991) emphasize the connections to identity and learning by writing, "…learning thus implies becoming a different person with respect to the possibilities enabled by these systems or relations. To ignore this aspect of learning is to overlook the fact that learning involves the construction of identities" (p. 53). The first sentence of this quote refers to a new identity transformation that is fostered when a student is welcomed into a learning environment that supports their current identities. If a student is to increase their scientific understanding and perspective, their non-scientific identities must also be supported.

Gee (2004a, 2004b, 2007), Reveles and Brown (2008), and Roth (2008) influence the ideas and questions behind this paper relating to science identity. These researchers have contributed heavily to the understanding of how the development of science identity correlates with success in science learning. While Roth, and Reveles and Brown are primarily concerned with science identity, Gee, however, explores the complex nature of school subjects in terms of domains (i.e., English, math, science, history). According to Gee (2007), in order for students to be successful participants in a particular domain, they must be able to understand and participate in the Discourse specific to that domain. Discourse includes the language and behavior recognized as unique to each domain. Therefore, there is a positive and direct correlation between science Discourse and the development of a science identity. Roth (2008), Reveles and Brown (2008) illuminate the complexities of the science domain and its corresponding Discourse, in order to identify the specific and appropriate skills students must develop to participate and engage in science learning. This process of developing a science identity requires students to develop these science Discourse skills. A fundamental investigation of this paper addresses the issue of access to science identity development, and specifically what educators can do to enable all students to develop of a science identity.

Controversies

One of the primary controversies encountered in science identity research involves the sacrifice of learning in the name of identity development. This idea suggests that if science education is constructed in ways that meet students where they are, then there is a reduction in optimal, standards-based learning. This traditional approach recognizes that progressive teaching strategies emphasize experiences, discourse, and reflection in order to give students a foundation for which they can construct conceptual understanding and a science lexicon. The more traditional approach to science education places importance on the memorization of terms, skills, and writing, leaving little curricular space for student driven activities.

Complementing the traditional approach is the claim that all students do not have the mental capabilities to learn and understand science. Influenced by this mentality, it is difficult to imagine how or why a student should be encouraged to develop a science identity. This notion will be challenged throughout this paper, as research reveals how science education and identity can be made accessible to greater numbers of students.

Limitations

While this paper focuses on variables that influence a student's construction of a science identity, the research specifically oriented towards science identity is limited. The concept of science identity in all its complexities has been explored primarily in the past decade, though research into the general psychology of an individual's science capacities stretches back further. Much of the latter body of work has been adapted to reflect more recent principle understandings of science identity and science learning. For example, Markus and Nurius (1986) use the term ‘possible selves’, which in this paper is interpreted as possible identities. Also, the process of identifying barriers students face when developing a science identity requires translating a lack of scientific engagement and achievement to a lack of a strong science identity. Whether these barriers are based on socioeconomic variables, past experiences, or disagreeable beliefs, they represent points of dissonance between a student’s pre-existing identities and a science identity. Ultimately, the critical review of science identity research within this paper is limited by a lack of research related specifically to recent science identity theory and applicable progressive teaching practices.

Summary

The concept of identify is a factor of an individual's ecological position in the world. That is "…we conceive of identities as long-term, living relations between persons and their place and participation in communities of practice" (Lave & Wenger, 1991, p. 53). Within the science classroom, it is impossible for a student to learn science if they are unable to connect the curriculum with their identity, as conceived within their greater community. While prior knowledge of students is critical for an educator to facilitate connections between them and the curriculum, prior knowledge must be considered in terms of a holistic and complex identity each student possesses. This paper will explore the nature of non-science identities and how these identities can begin to open space to accommodate a science identity.

CHAPTER TWO: HISTORICAL BACKGROUND

Introduction

This historical analysis explores science-identity related concepts and research from the past few decades and forms the foundation for more recent identity research critiqued in chapter three. One main idea embedded in this section concerns the complex nature of identity and why it is an important variable in understanding why some students struggle to engage and achieve throughout their science education. Using this understanding of identity, the major variables that help form science identity will be reviewed. These variables include science Discourse, science literacy, and issues of access to science curriculum. With these variables better understood, a deeper investigation into what impedes or stimulates a science identity can take place.

Recognizing Identity as an Important Factor in Science Learning

To better understand the concept of a science identity and its connections to science learning, it is important to review the various research and ideas concerning identity developed by educators and scientists in recent years. A common thread found throughout this research affirms the idea that identity is a complex construction influenced by numerous factors that are proximal to an individual. This research also acknowledges that the process of developing identity is a continuous and constructive practice that unfolds in multiple contexts under multiple influences. If educators are to help students develop specific identities oriented towards specific learning domains, then the individual's influences and current identities must be recognized. The following historical analyses help form the fundamental lenses used to interpret the major research discussed in chapter three.

Gee (2007) influenced the major framework driving the vision of this paper. According to Gee, all learners experience a triangulated form of identity that includes a real, virtual, and projected concept of self. The real identity emphasizes one's existence and self-perception at this moment. A virtual identity refers to a potential version of one's self with new features, limits, experimentations, and inputs one contributes to this virtual self. This virtual identity is also affected by the interactions and perceptions of one's surrounding community. A final, synthetic 'projected' identity is then produced which includes the successes and realizations obtained through experimenting with your real and virtual identities.

This theory offers great insight into science curriculum and classroom design, and educators should consider essential ideas and assessments to be based on the growth of one's projected identity. In the science classroom, this process involves creating activities that allow students to practice engaging with their virtual identities. In the case of a science identity, this means that students are able to extend their real identities in class to include virtual aspects of what it means to practice and be engaged with science, all the while relating to this virtual identity through their more familiar real identity. Of course, the gaps between real identities and virtual science identities must be recognized and appropriately bridged by the educator.

Gee (2007) recognizes the high variance of Discourse communities within American culture, and discusses a necessity to bridge gaps in order to reach distant and uninterested students. This sociocultural diversity within the United States has led to the development and sustenance of specialized interests, pursuits and cultural practices. In this sense, there is a considerable challenge for teachers to connect scientific significance with students' different passions and cultural backgrounds. Not only must educators be aware of the knowledge and practices students bring to the classroom contained within their real identities, but also they must be aware of the non-science inputs students are using to construct their virtual and projected identities. In other words, to better help students integrate a science identity into their virtual and projected identities, educators must pay cognitive attention to how students are viewing their growth. For example, if a student is developing a projected identity that includes involvement in a performing arts domain, a science educator could help this student make connections between both domains. The performing arts teacher could use the same process as well. Gee's concept of identity reflects a pedagogical concern to know students' past, present, and future identity characteristics and an ability to adapt this information into an integrated curriculum.

Similar to Gee's construct of identity, Markus and Nurius (1986) apply the concept of 'possible selves' to how students learn. The possible selves theory is closely related to Gee's theory of projected identity, which includes a prospective view of the self relative to present and past selves. The possible selves theory includes aspects of identity an individual hopes to develop as well as aspects an individual is afraid to develop. If a student is to develop a science identity, he or she must consider science learning to be beneficial to a possible self. For some individuals who have constructed barriers towards science learning, developing a science identity is most likely contradictory towards a possible self, therefore, making science learning difficult.

The possible selves theory operates under principles of viewing identity as a fluid and constructive process (Foucault, 1978). Identity is therefore never limited to a solitary and unchangeable structure, though an individual is capable of constructing various barriers that could confine identity to a specific set of behaviors and thoughts. A fluid identity enables an individual to adapt to changing environments and social settings, thus increasing opportunities of participation with other social groups. Maintaining a perspective of identity as a fluid construction allows educators to view the potential within their students as opposed to confining them to their current states of identity. This process also encourages students to take a metacognitive approach to constructing their identity, giving them the opportunity to make connections between various activities and experiences in their lives. If a science educator were to view their students as fixed individuals with pre-established identities, the educator would offer little scaffolding in science learning should a student exhibit no evidence for possessing a science identity.

A supportive learning environment, however, transgresses the classroom and includes an individual's collective interactions with the world as described by bioecological systems theory (Bronfenbrenner, 2005). This theory suggests that an individual develops according to conscious or unconscious interactions with family members, local businesses and institutions, the ecological environment, and greater societal structures such as government institutions and policies. This conceptualization of identity gives credit to non-school psychological factors that inevitably affect each individual. Applying a bioecological lens to science education encourages educators to recognize possible ways students interact with science concepts outside of school, and include these experiences in classroom curriculum. As education ultimately involves the creation and application of lenses for which students either adopt or reject for interpreting their world, much of this process can occur within the classroom. However, if this information does not connect with a positive and constructive view of the world a student develops outside of school, the student will not have incentive to adopt a science identity into their collective identity.

The bioecological lens lends itself well to understanding how barriers towards developing a science identity are constructed. If an individual encounters negative experiences with science or is not encouraged to question the "hows" and "whys" of the world around them, it is possible that an aversion or ignorance to scientific thought may develop. While these barriers may be constructed in an actual science classroom, there are several ways an individual might develop a dislike towards science while engaging with their world outside of the science classroom. The bioecological lens enables science educators to explore and critique the various levels in which an individual interacts with their surrounding communities and greater society at large. Bioecological theory seeks to expose the dissonance between an individual's various encounters with the world to better establish a system of support for an individual's construction of a collective identity, and more specifically a science identity. Science educators can use this awareness to create an emotional and socially supportive learning environment.

Bioecological theory also helps to explain why it is difficult for students to learn science when science curriculum is presented entirely as a collection of facts and laws. As students use various and unique identities when engaging in a classroom, it is unlikely that all students will be able to develop a conceptual understanding of science concepts if they are not presented and worked with in an accessible context. Science educators can construct appropriate learning contexts by developing an understanding how students interact with outside of school. These contexts are vast and diverse, including any extracurricular activities, individual or social that a student engages with beyond the classroom. To do this effectively, science educators must work to maintain open lines of critical communication with their students and the factors that influence their student's identity development outside of the classroom.

Similar to bioecolgoical theory, science identity may also be understood in the context of an individual's 'lifeworld' (Kozol & Osborne, 2004). Lifeworld refers to the various identities an individual applies to operate within and interpret their worlds. Kozol gives an example of how one particular student's lifeworld inhibited his yearning to develop a scientific identity. Hector, a Mexican immigrant, was unable to connect science curriculum to his life and progress in the U.S. Hector was a member of an agricultural community populated with many other Mexican immigrants. From a scientific perspective, much can be applied to Hector's life, such as the chemistry and danger behind chemical pesticides and fertilizers, as well as what variables constitute quality agricultural lands and locations. In Hector's lifeworld, science was a foreign subject which served no utility. However, Hector's lifeworld could be expanded to include those scientific variables close to his home, thus making science a potentially more intriguing and applicable knowledge. By figuring out how to expand students' lifeworlds, educators can better create a space where scientific identity can be desired and accessed.

The previous paragraphs helped to further delineate how I interpret the construct of identity and how it is applied in an individual's everyday interactions. The next passages will attempt to reveal how science Discourse is a fundamental component of a science identity and how the specific nature of science Discourse can prohibit students from developing a science identity.

Science Discourse and Literacy

The connections between language and identity are powerful. Each semiotic domain has its specific form of language that makes it unique in its orientation to understanding the world. The science Discourse community is rich with rules and expectations regarding language use. The extent to what is acceptable science language in professional venues versus classroom discourse is a prominent issue of debate, as the learning of scientific language is necessary to decode the abstract scientific realities around us. According to Halliday and Martin (1993), scientific language enables the scientist to organize the world through classification, composition, and diagramming processes and phenomenon, whereas colloquial language will only allow a shallow, and perhaps even, misconceived understanding of the scientific world. This exclusive, evolved nature of scientific language offers one context in which scientific understanding can develop. Gee (2004b) suggests that though everyday language is crucial when inviting young nonscientists into a scientific domain and when making cross-curricular connections between science and other domains, it "…obliterates the underlying mechanisms…that are the heart and soul of physical science" (p. 32).

This position assumed by Gee, and defined by Halliday and Martin (1993), emphasizes an important effort to maintain the integrity of scientific language. As language plays a crucial role in developing a science identity, then it would seem that only those who are fluent in the highly exclusive scientific discourse have the potential to develop a scientific identity. It is this issue that appears and reappears in past and current debates over the usage of scientific language in the classroom.

While students in the U.S. maintain lower levels of science achievement than several other nations (National Center for Education Statistics, 1995), the challenge for the majority of students in the U.S. to develop scientific identities through science language acquisition is apparent. Again, since science Discourse consists of highly specific language, it makes sense that students engage in science Discourse as if it were a second language. However, this does not mean that scientific language should be reduced to a set of grammatical rules. The notions of linguistic accessibility are an essential concern in increasingly diverse and multicultural classrooms across the nation. To make science accessible for all students then is to enable all students to speak and behave as one in a scientific discourse community.

One positive step in this direction in the last few decades has been the inclusion of earth-based education and intervention programs into science curriculums. These programs allow students to live in the field for a period of time (often no longer than one week) and experience the scientific method in a contextually, stimulating environment. Students engage in hands-on applications within a structure parallel to observational and interactive, scientific settings. As these programs are often conducted in experiential settings, students are able to create and develop new scientific identities in the context of their established social identities. This heavily immersive experience benefits from abundant sensory stimuli, kinesthetic learning, and a large amount of contact with a functioning scientific community outside of the classroom. When considering the components that make discourse communities inviting to many, these experiential variables found in successful earth-education and science intervention programs could be adapted to classroom scientific discourse communities.

Indeed, several linguistic, experimental, and inquiry elements are being advocated by national science research groups and the scientific community and implemented in classroom settings. While students still need to learn how to become efficient in accessing storehouses of scientific information (Halliday & Martin, 1993), practicing the fundamental science techniques engrained in the scientific method is important. The traditional approach of learning science language through memorization, repetition, textbook-learning and non-objective approaches alone is being recognized as an ineffective method for alluring and developing students to be scientists. The alluring aspects of science, however, do not end once science learning increases in complexity and a more defined Discourse. Recognizing the role of the individual in scientific practices makes this point. One of the primary motivators of identity development is the connection between the self and a Discourse community. That being said, students learning science can be easily discouraged by the 'one right way' to talk science, and fail to connect with the material explained by a sterile language.

As traditional science teaching involves rigid adherence to science language rules that demand a removal of the human factor, students' interpretations of concepts, forces, and processes, laws exist apart from the more important social aspects of their realities (Lemke, 1990). Science language follows passive voice conventions, in which findings, theories, and laws are stated as assumed fact. When these statements are explored deeper, human agency is revealed in the form of the scientist, or the expert, roles that students often believe to be highly advanced and impossible to achieve. Lemke advises teaching against this 'mystique of science' by appropriating values of perspective and progress, rather than teaching science from the angles of fact and proof.

Issues of Access to Science Curriculum

Another way to consider the development of science identity is to consider the concept of barriers as an issue of accessibility. For example, the work of identifying specific barriers students encounter in the process of developing a science identity could be reframed in the context of accessibility by specifically exploring who has access to developing a science identity and why. To begin this process, it is necessary to identify the curricular and representative constructs of Western Science.

Scientific practices embody peculiar ways of exploring our reality. These practices invent and utilize tools that allow us to manipulate physical and potential variables to alter our state of existence. Western science has traditionally represented a mode of thinking that is exclusive and objective, reserved for the professional realm of middle to upper class, White male individuals with a high level of intelligence (Letts, 1998). In viewing science as a Western cultural construct, students who come from more traditional Western cultural backgrounds have a convenient and advantageous platform from which to develop a science identity. With scientific role models represented by intelligent white, male, upper class identities, students of this particular identity have had greater access to the development of a science identity. This limited the pursuit of scientific knowledge to a small and privileged population within the U.S.

With science exploration and knowledge driven by such a small homogenous population, the viewpoints of the majority of the population on Earth have been excluded. While the philosophy of science values an objective, rational and logical approach to understanding the world, this cannot be achieved if science continues to exist in a cultural vacuum (Harding, 1998). Harding encourages science to value and integrate contributions from multicultural and non-traditional populations. In this process of enriching the present-day collections of scientific conceptions, science will become recognized for what it is; a methodical perspective used to increase our understanding of our realities.

Summary

In closing this historical analysis of the foundations of science identity, it is important to recognize the primary elements that construct identity. Some barriers have already been identified pertaining to linguistic, gender, cultural, and economic attributes.

The common outsider perspective of science devalues science because science concepts cannot be connected to, supportive of, or are too contradictory to an individual's lifeworld. In addition to these variables, the participants of science often approach science as an objective practice that is free from cultural influence. This perspective is not shared between all individuals, many of whom devalue science as a mode of thought steeped in Western culture and Western biases. These barriers will continue to be explored in the following chapter, as will the ideas that pertain to overcoming these barriers.

CHAPTER THREE: CRITICAL REVIEW OF LITERATURE

Introduction

Thus far, this paper has examined the theoretical and historical importance for students to develop a science identity in order to understand science concepts. It is the process of developing a science identity in which educators must explore and critically engage with if science curriculum can be made accessible to all students. In the following literature review, specific forms of barriers towards developing a science identity will be explored. Also, ideas for how to create bridges for students to move through barriers en route to developing a science identity will be critiqued.

The first section of research in this chapter explores the extent to which science students find congruency between their non-school worlds and classroom science learning. Much of this section attempts to identify how successful science students have science identities that are supported in non-school settings. The following section investigates how non-traditional science populations develop science identities and why they often face challenges doing so in science classrooms. Transitioning from minority science populations, the next section explores patterns of male and female gendered science identities and how these identities are supported by gender prototypes in mainstream science communities and classrooms. The following section investigates how science identities are formulated and supported throughout science education. This section will also focus on research that identifies how science concepts, values, and competencies transition from year to year in a science classroom. Research on Discourse communities and contextual shifting will be critiqued in the next section. This research focuses primarily on how language, practices, and learning styles within science classrooms dictate the development of science identity. The following section analyzes research on how more specific language discourse modes, such as talking, reading, and writing science create issues of access to developing science identity. In the next section, research corresponding to the support of individual science identities within cooperative group structures will be examined. The final section will investigate progressive ideas within literacy, such as the use of web technology, experiential settings, and increased group discourse to help students internalize science identity and science conceptual learning.

Another World: Congruency with Science Education

The research in this section is based on the connections between identity and relevancy. In order for a student to engage in science learning, the learning must be applicable to the students' perspective of life. This perspective is rooted in one's identity. In an educational sense, relevancy of coursework is what enables students to successfully access science domains. Are students able to connect their culture, career potential, socioeconomic status, and prior experiences to their science learning? If students are to find classroom science curriculum to be relevant, there must be congruency between their non-science orientations and the science models they are engaging with in class. Integrating resources and knowledge from students' non-science domains into science curriculum requires knowledge about the various identities students bring to the classroom.

Knowing the worlds of students is essential for a community of mentors to best guide student development. Constructing this knowledge could be accomplished by utilizing an anthropological lens. This could help science educators determine their students' worldviews, and thus create a scientific curriculum that integrates a scientific worldview to the worldviews of the students (Cobern, 1994). Cobern's use of the term ‘worldview’ is closely related to what constitutes identity. Engaging students through inviting them to express their worldviews is akin to inviting students to safely express their identities. The techniques and benefits of such practices are explored in the following research examples.

A qualitative research study conducted by Kozoll and Osborne (2004) focused on three participants and how successfully their science education fit into their worldviews. The researchers used the term 'lifeworld' to define their participants’ identity/worldview structures. Lifeworld refers to the experiences and interactions an individual engages in within his/her community and the knowledge, beliefs, and influences that correspond with those interactions. After conducting several interviews and analyzing the dialogue, the researchers identified some barriers and bridges that influenced the level of development of scientific identity for each participant. The particularly interesting variable of this study was the researcher’s selection of participants. The participants were minority students who experienced childhood contexts that involved migration transitions between various farming communities in the central areas of the United States. The following section will identify the participants of this study and will illustrate the need for teachers to understand their students’ lifeworlds.

For one participant, Hector, education was viewed as a way out of poverty and the difficult migratory lifestyle (Kozoll & Osborne, 2004). In the various demographically different communities Hector lived in, he became familiar with cultural stereotypes and the means of which minority students fail to achieve in the education system. Though Hector did not develop a belief that science embodied a useful knowledge that would help him succeed in a professional career, he valued education as the alternative to the struggles his peers continuously endured upon dropping out of high school. Despite the immense relevancy of science within Hector's agricultural background, at no point in Hector's science education was he encouraged to consider the connections between science and his lifeworld.

A similar example occurs in the case of Clara (Kozoll & Osborne, 2004). After spending a childhood migrating and working during summers in cucumber and strawberry fields, Clara knew from an early age the migrant farming lifestyle was not an occupation she desired. Like Hector, Clara viewed her science education as a difficult, fact-based endeavor. But in high school, Clara had a science teacher who made learning science 'easy' and created opportunities for students to construct scientific knowledge based on inquiry and experience. Clara's group project, researching the local landfill, was a positive social experience that provided her a 'real-world' application of the scientific process. This example of working with a local landfill allowed Clara to connect her science learning to a cause that directly is directly effected by and impacts Clara and her community.

Clara's development of a scientific identity was also a social and future-inspired process. During her youth migrating between different Texan towns, she developed a self-perception as an outcast, which was fueled by peer comments and exclusion. She enjoyed nature and perceived her success in life would best be accomplished through self-focus and her education. Through her science education, she gained knowledge that related to nature and aided her translation of natural phenomenon. In this process, she was accepted by similar-minded peers and valued her newfound, positive social interactions.

Kozoll and Osborne (2004) designed a valid study by conducting six interviews with each participant that enabled them to discuss the deeper issues of their subjective experiences. This also allowed ample space for frequent member checking with participants, for the researchers to confirm their interpretations and discuss both parties' reactions, ideas and conclusions. In the conclusion of their study, the researchers assumed the positive influence of socially constructive and culturally relevant experiences in shaping students science identity to include the domain of science into their lifeworlds. Kozoll and Osborne (2004) wrote "…the self is created in the very process of interacting with others and the environment (p. 173)."

The identity forming processes that occur with the self and the environment are catalyzed by the individual's perceived congruency between their various worlds. This means that new identities, such as a science identity, have greater potential to develop if the student recognizes connections between their non-science worlds and the world within the science classroom. Phelan, Davidson, and Yu (1991) developed a keystone categorization of congruency levels in adolescents' worlds that range from highly congruent worlds to non-congruent worlds. Applying Phelan et al., concepts, Costa (1995) explores the levels of congruency between students' worlds outside of school with their particular worlds inside the science classroom. Costa's research helps to identify borders that separate students into identities that may or may not be congruent with science learning and classroom culture.

Working with 43 participating high school students from earth science or chemistry classes, Costa (1995) constructed five categories that described the spectrum of congruency between students' school and home worlds. These categories, which will be explored in more depth below, include Potential Scientists, Other Smart Kids, I Don't Know students, Outsiders, and Inside Outsiders. Then Costa chose eight particular students, with all categories represented.

In the description of her students, Costa provides rich excerpts from interviews and classroom dialogue that are explicative of students' successes and struggles in their science education.

Interpreting Costa's (1995) data through an identity-based theoretical lens, it is easy to see how congruency between worlds helps to foster the development of a science identity. For the Potential Scientists, science was a subject that was frequently discussed at home, and could be connected to various activities that those students participated in. Though the Other Smart Kids did not have particularly strong science identities, they valued science on platform of education success, which allowed them to succeed in science learning. The next three categories found little success in science class and were failing to develop science identities. The I Don't Know students appeared to lack motivation towards any identity, as school worlds and home worlds were based on routine, politeness, and satisfactory achievement. Costa mentioned little of the Outsiders, primarily describing them as detached from school with little support for school coming from their other worlds. The Inside Outsiders suffered the most from incongruent worlds. These students had been labeled and tracked by the school administration and were likely to never see positive guidance that encouraged educational success or participation in science class. Incongruence in these students' worlds often translated to responsibilities outside of the school and prior academic history that was interpreted by the administration as an inability to learn.

In order to identify bridges and barriers for students in developing a science identity, Costa (1995) relied on the expressed self-perceptions of the participants. Costa collected student input during 50-minute individual interviews. One critique is that the length of the interviews could be extended to allow for a deeper understanding of participants perceptions.

Also, a deeper, prolonged observation of students in their classroom and home contexts could reveal a better understanding of the incongruencies between students' worlds. This could also lead to a less essentializing approach that could transcend a five category codification based on grouping labels, and instead implement a non-hierarchical codification based on types of barriers and motivators.

Costa's (1995) research reveals that the barriers to developing a science identity that deserve particular emphasis here could be attributed to inequity. As interpreted from her insider/outsider examples, if students are failing to be encouraged or positively reinforced to succeed in science at home and in their non-school worlds, then the weight is born upon the school staff and administration to help students succeed. This heavy role of educational responsibility that equates to accountability is often not enough to facilitate positive science identity formation. If students cannot connect or do not receive support to internalize scientific material, then there is little space for science discourse and thought to take root, and therefore a science identity to develop.

The accommodation of student identities into science curriculum is one method currently being researched to help bridge students towards developing a science identity (Upadhyay, 2006). Upadhyay attempted to identify ways in which teachers determine which student experiences and funds of knowledge are important and then how teachers integrate these student experiences into their science teaching. This research was conducted in a fourth grade science classroom over a period of two years. Upadhyay extracted findings from the analysis of eight videotaped science lessons and 12 teacher interviews lasting two to three hours each. The student body consisted of predominantly Hispanic students, while the teacher was White.

Upadhyay (2006) claims the teacher often created space for students to share their lived experiences, while putting forth a strong effort to connect her experiences with those of the students. While the researcher provides a strong theoretical backing for the teacher's actions, he includes few examples in his paper that identify how the teacher successfully integrated students funds of knowledge into the science curriculum. Though the study was prolonged and persistent, excluding students, teachers, and parents from the interview processes reduces triangulation.

There were some interesting issues of diversity explored within this study (Upadhyay, 2006). First, The teacher was working in an urban setting with primarily Hispanic students. As identity bridging requires students' self-expression and reflection upon their own identities, the teacher must also be successful at interpreting what these expressions signify. Only in a satisfactory interpretation can students' lived experiences be connected to the course curriculum. For example, if a teacher is unable to interpret his or her students' experiences with an objective lens from the student's perspectives, then there is potential to fail to connect curriculum in the classroom with the students' prior experiences. Upadhyay does not provide evidence as to how the teacher interpreted her students' funds of knowledge. There is some evidence that suggests the teacher in this study created a space for students to reflect upon and share their personal stories, but the interpretation and integration of these stories remains unexplained.

The effectiveness in connecting science learning with real life experiences and potential realities of students pertains to congruency and relevancy of curriculum. When science is linked to intimate and applicable venues in students' lives, such as family, future goals, and personal values, science learning and science identity development is increased (Thompson & Windschitl, 2002). Thompson and Windshchitl analyzed the discourse of five at-risk adolescent girls' in the context of relevancy and engagement in an attempt to determine in what ways science curriculum could be made more engaging. In order to determine how a student relates to an activity, relevancy to their personal experiences and identities must be known and accounted for. The researchers postulate that at-risk youth suffer in educational contexts because teachers have difficulty identifying how science could be personally relevant to these youth, outside of grades, scores, and academic success contexts.

Thompson and Windschitl (2002) researched and interviewed five at-risk females, all attending public high schools (> 1500 students) in a large metropolitan city in the Pacific Northwest. These students, four sophomores and one junior, had failed their first semester science class and were currently struggling with attendance and science grades. Two separate interviews lasting one hour each were conducted with each student. The first interview focused on personal relevancy as students answered questions about how their education was meaningful. The second interview explored similar topics but in a science-specific context and how they viewed science in comparison to a student they knew as a good science student. This case study was also informed with data shared by the girls' science teachers.

During the questioning, all girls described how their extracurricular activities, such as photography, acting, and athletics were personally relevant to the girls and triggered the self-connected motivations of beliefs, values, and learning specific skills (Thompson & Windschitl, 2002). When describing science, the girls all describe specific science tasks, rather than the entire scientific pursuit, as having personal relevancy to their lives or to a lesser degree, a situational interest. For three of the girls, certain science activities are connected with a sense of self. Also, the girls describe typical values common to adolescent girls; the researchers connected these beliefs about *who they are, who they are becoming,* and *the importance of relationships* to engagement in science curriculum. All the girls seemed to understand why science was important, but still struggled to engage with the curriculum. Of the science projects they engaged in successfully, all were directly related to their pursuits or correlated with their familial relationships in some way. The researchers strengthened the validity of their study with detailed, in-depth discourse analysis of the interviews, and triangulated their interpretations with multiple sources of adolescent development, education motivation, and curriculum engagement.

Of the girls' responses described in the paper, it was hard to distinguish motivational variables that would consistently maintain high levels of engagement. For these girls, there was little satisfaction or motivation to succeed if the curriculum did not directly, literally, and obviously apply to a situation in their lives. For example, how could levels of student engagement be increased through hidden variables not yet perceived? This work could be expanded to include how at-risk adolescent girls could increase their perception of how connected seemingly insignificant curriculum could be to their lives. Direct application is an obvious motivator for disenchanted youth, but with a large curriculum, multiple identities, and varied interests within one classroom, it seems unlikely that direct application of all curriculums could be made relevant to each student's lives.

Based on the research in this section, it seems being able to link science curriculum to the non-science worlds of students is critical, if a teacher is to create a space for each student that is conducive to the development of science identity. By first identifying and appropriately interpreting students' prior experiences and knowledge, teachers can then work to create meaningful curriculum that engages the non-science identities students possess. With these studies involving mostly participants of minority populations who traditionally have had little representation in the mainstream science community, it is reasonable that these students might experience incongruent worlds in their science education. The next section will evaluate research that explores the science experiences of minority populations with an interpretative lens.

Interpretations of Minorities in Science Education

Having applied some research to minority populations who face significant challenges in adopting a science identity in Western schools, this section will review additional research that explores variables that influence academic identity such as self-concept, locus of control and socioeconomic status.

Success in a particular school subject is often evaluated by a student's level of achievement. Achievement scores can be a satisfactory signifier of a student's ability to internalize information and do well on summative assessments, however, do achievement scores signify levels of a student's science identity? Using data collected during the National Education Longitudinal Study, Chang, Singh, and Mo (2007) explored the relationships among science achievement, locus of control, self-concept and ethnicity. Locus of control refers to how much control an individual he/she believes to have over his/her life. Self-concept refers to how positive or negatively an individual views his/herself. This quantitative study involved two analyses of questionnaires completed by students when they were in eighth, tenth, and twelfth grade. The study benefitted from a large sample size of 12,144 students, selected nationwide. Four ethnicities were categorized, consisting of 8,031 Caucasian students, 1,172 African-American students, 1,618 Hispanic students, and 844 Asian-American students.

Students with the highest consistent science achievement scores throughout high school were Asian-American and Caucasian students. With the achievement data, Chang et al. (2007) then ran correlational analyses to identify that variables were more correlated with the achievement statistics. While African-Americans recorded the highest levels of self-concept, they had some of the lowest achievement scores. However, for the Caucasian and Hispanic populations, self-concept was significantly correlated with achievement scores. Locus of control was the only variable significantly correlated with achievement scores in all groups of students. That is, if achievement scores were high, so was locus of control scores for the particular group and if achievement scores were low then so were locus of control scores. These findings suggest the power of locus of control in affecting science achievement.

In an effort to connect the concepts of locus of control and self-concept to the nature of identity, it would be helpful to better understand the questionnaires used in this study. However, this information is not given and, therefore, the efficacy of the questionnaires is questionable. Assuming the questionnaires adequately measure locus of control and self-concept, then the next inquiry should relate to how these variables influence a student's identity. That is, further research exploring the correlations between a student's locus of control and his/her level of perceived science identity. As this study claims locus of control to have a more significant effect on science achievement than self-concept, educators must work to empower students and instill in them a sense of control over their learning. In this sense, knowledge could best be presented as a malleable construct in which students understand learning to be a developmental process, rather than a fixed entity structure which restricts learning to innate capabilities (Dweck, 2007). Allowing students to construct their learning experiences by including their voices and experiences reveals to them that science education is not itself a fixed set of information and activities, but is determined by those who engage in creative classroom activities and practice scientific thought processes.

To apply the lens gained from Chang et al., (2007), the following study was conducted in an urban science school whose guiding questions revolved around creating a culture of academic success (Buxton, 2005). The Center for Science and Math (CSM) was designed to teach science, math, and technology from the perspective of the scientist. Thus, the teachers hired were primarily science experts within a particular field. Students attended CSM, based on interest, for half of a day and then returned to their 'home' high schools. Ninety percent of the student body was African American, and 73% qualified for free or reduced lunch. Every neighborhood and each of the 30 schools within the city were represented in the student population of 325 at CSM. Fifty one percent of the city where CSM is located lives in poverty. Classes particularly focused upon in this study were ninth grade physical science and chemistry, tenth grade geology, and twelfth grade physics.

Buxton (2005) found that students who arrived at CSM as freshman were unprepared to meet demands and visions set forth by CSM missions and teacher expectations. They routinely struggled to do adopt the institutional model of an educated person, despite receiving good grades at their home schools. Students pressured teachers to lower expectations by resisting in forms such as copying, cheating, complaining, being passive in class, and pretending to be knowledgeable or unknowledgeable. Students who remained at the school for longer than two years most often went on to graduate at CSM. Buxton thus found distinct differences between long term and short term CSM students. Students that often left CSM gave reasons such as difficulty and the desire to get good grades to get into college. These students reasoned that achievement in high school meant getting grades to get into college, whereas students who graduated from CSM said their achievement was based on how competent they were in competing academically in college.

In terms of school culture, the administration at CSM recognized there was a high dropout rate for students within their first two years at CSM and tried to enhance connections with feeder schools to better prepare students in middle school. Often times, freshman teachers at CSM negotiated heavily with students in efforts to keep students motivated towards learning. This was another sharp divide between lower classmen and upper classmen. In terms of teachers who stayed on at CSM for more than three years, they tended to view 'funds of knowledge' that students bring as an important starting point for student learning. Teachers who left CSM early tended to view students' backgrounds in terms of cultural deficits.

There are some definite strengths to Buxton's (2005) research. First, Buxton mentions an extensive use of member checking during interviews and vignette construction. Also, given his experience as a past teacher in the school, he possesses an acute socioeconomic and cultural understanding of the district, community and population of students.

Both studies in this section identified achievement patterns that are common amongst student populations that are traditionally challenged in science education. Chang et al. (2007) suggested that locus of control seems to play a role in achievement scores while Buxton (2005) reaffirmed the necessity of prior knowledge recognition amongst science teachers. In these cases, barriers to developing a science identity appear to be a perceived lack of control over learning and a failure on behalf of science teachers to empower students and include their previous experiences. Meeting students where they are at in terms of knowledge and creating curriculum with mechanisms that increase a student's locus of control could be beneficial to the development of science identity. The following section will continue to explore the potential to develop science identities within students who possess specific identities that are often marginalized within their communities.

Marginalized Identities

When talking about identity, there are an infinite amount of factors that can act as barriers for students towards developing a scientific identity. Much research shows a major factor in inhibited identity development is socioeconomic status, in which education favors White, middle-class, masculine, and heteronormative features (Harding, 1998; Johnson, 2006; Lewis, 2008; Valenzuela, 1999). These features encompass the majority of the U.S. population and contain a multitude of sub-variables and facets of identity construction that will be explored in the following paragraphs. Socioeconomic status can be linked to minimally funded schools, unskilled and unprofessional teachers, school segregation, and provide a lack of motivation to explore further educational and professional opportunities, let alone a scientific identity. In the dominant Western society where science is viewed as intellectually objective and a pure form of logical processing, the pursuit of a science education that is accessible to all students contradicts human processes of cultural variance, diverse thought, and the failure to recognize the biases of Western science.

A population that has consistently been excluded from educational opportunities and scientific realms are the various cultures of American Indian populations. If we are to isolate socioeconomic variables for a moment to focus on blended identities within American Indian students, we can identify specific barriers that block the development of a scientific identity. Blended identity refers to an individual's collective identity. In this study, the identities of the American Indian participants are being deconstructed into two categorical identities, Anglo and Indian.

James (2006) explored the complex identities of 196 American Indian high school and college students from Native populations along the West coast, Colorado, and South Dakota. Using the Cultural Identity Inventory, Kluckhohn's Inventory, and the Cognitions and Beliefs about Technology and Science questionnaire, James isolated Anglo and Indian cultural and identity values within his participants and found relationships between cultural identity and scientific values. In this study, it was possible for participants to maintain both Anglo and Indian identities within each of the same questionnaires. James then used multivariate testing to see if certain identity features correlated with beliefs about technology and science.

Significant correlations were found between cultural values and beliefs about technology and science. For example, while Indian identities were negatively correlated with Individualism and Mastery over Nature, Native Americans with Anglo identities were positively correlated with Future Time Orientation and Individualism. This suggests that the individualistic, future thinking, and 'dominance over nature' tendencies of Western science oppose Native American identity. In addition, James also found that Native American identities consider technology to be socially and environmentally damaging, not heroic, and empty of spiritual and negative positivity, while Anglo identities considered technology to be heroic. This research suggests obvious implications within the science classroom.

James' (2006) analysis is strong in several ways. First, the Anglo/Indian cultural identity questionnaire he chose was developed by Oetting and Beauvais and is regarded as an effective measure for determining the internalization of cultural characteristics. In this questionnaire, the participants could identify as either Anglo or Indian for each question, and therefore identity was highly variable. In developing the final questionnaire issued about technological and scientific beliefs, James consulted other faculty members, subject matter specialists, and Ph.D. students. This collective effort to compile essential questions is representative of a nicely designed study. Linking this research back to the thesis of this paper, there is a definite barrier for Native Americans who identify as Indian to develop a science identity. In an effort to make science education accessible to all students, the solution does not lay in shaping more Native Americans to develop Anglo identities, but rather diversifying the aims of science, to include more Indian perspectives. Science by nature does not translate into the individual pursuit of a dominance over nature or technological advancement; these are schemas perpetrated by the Western cultural view of science.

In another study seeking to further awareness in a general context of American Indians' self perceptions, Fryberg and Markus (2003) compared self descriptions of American Indian with those of European American college students. The researchers worked with two inter-raters, one American Indian and one European American, to identify conceptual labels for which the participants' descriptions could be categorized. Participants' responses were then tested for correlations with their identity (American Indian or European American).

The researchers found significant evidence that is congruent with similar research which suggests American Indians are less focused on their immediate situations and emotions, and identify more with their desire to support their families and improve themselves. In contrast, European Americans were more likely to identify themselves in terms of their abilities and immediate emotional states. European Americans were also slightly more likely to describe themselves with positive attributes. Due to its specific population of participants, these results were limited in transferability. Being college students, these American Indians have achieved fairly significant success already, representing a small percentage of American Indians that pursue post-secondary education (U.S. Department of Education, 2006). By allowing participants to respond to an open-ended question inquiring about their identity, students constructed a wide variety of identifying traits, and were not limited to the structure of more formal personality and identity questionnaires and surveys.

Fryberg and Markus (2003) research supports the supposition that American Indians maintain a different way of thinking and identifying themselves than European Americans in ways that are socially and improvement based. When considering bridging strategies within the classroom, it should be worth considering more social and collaborative aspects of science, that allow for students who are more socially forward thinkers to view science as an accessible tool that can help strengthen communities and maintain relationships.

A main component involved in Native American learning styles is the important teacher role played by community elders (Pewewardy, 2002). Integrating knowledge from community elders into learning in a science classroom not only recognizes students' funds of knowledge, but it values traditional ecological knowledge (TEK). TEK is an information base that offers traditional intellect based on observation and application and is passed down from generations in native communities. Although not recognized by Western science as scientific, this knowledge is derived from similar methodology used in scientific practiced and seeks to interpret, understand, and survive in a surrounding environment.

Sutherland (2005) used qualitative and quantitative measures to extract a better understanding of how students of Cree ancestry internalize scientific identity to the benefit of possessing and maintaining TEK. His study involved 20 participants from a Cree community. The textbook used in the classroom was designed for a seventh grade level, though students in this class ranged in age from 11 to 15 years old. For the first part of the study, participants responded to a questionnaire titled the Children's Academic Intrinsic Motivation Inventory (CAIMI). Two interviews followed, one of which asked participants about their levels of school engagement, future orientation, and intrinsic and extrinsic motivation factors. These responses were then analyzed to measure the participant's individual and family support within the four categories. A second round of questioning inquired into students' access to and possession of TEK and scientific knowledge. The findings suggested that students who ranked high in the protective factors were also students who were more likely to engage in collateral learning and combine both scientific knowledge and TEK. This correlation suggests that TEK and scientific learning are intrinsically linked for many Native students and could foster increased scientific and intrinsically motivated identities.

Participants gave several examples of TEK during the interview process, making the link between TEK and science learning to be quite apparent. The findings in this study are supported by ecological systems theory, a theory where an individual's sense of intrinsic motivation, knowledge construction, and engagement with activities is influenced by the larger community and not just the individual's teacher. One critique of this study however, is the lack of inclusion of the teacher's practices with the participants. Without this information it is unknown how students' TEK was integrated into the curriculum, important knowledge for helping bridge native populations towards a science identity and greater increase the scope of scientific knowledge to include that of Native populations and other non-western identities.

These articles (James, 2006; Fryberg & Markus, 2003) provide reason for further research into creating culturally responsive curriculums that allow access points for students with identities that are counter intuitive to Western science practices. Specifically, methods for integrating cultural knowledge and science techniques of Native populations need to be advanced. James' research suggests that there are underlying identity structures within Native identities that are extremely resistant to the culturally hegemonic practices of Western science. To respond to this, educators must not only consider the dissonance students with marginalized identities encounter when learning science, but also whether or not their science curriculums are promoting values that continue to harm cultures and the environment. According to Sutherland (2005) science education must involve components of preservation and propagation of TEK and Native American cultural identity, if students are to develop a science identity.

Prototypical Gender Identities in Science

Like cultural identities, gender identities represent another critical component in the process of scientific identity development. During an identity-constructing process, the individual will look to prototypical models to help guide their identity development. In connection with identity, a prototypical model offers an accessible symbol for Gee's (2007) projected identity. Male students or students who identify with more traditionally masculine qualities can construct projections based on several prototypical models, considering that males hold the majority of professional occupations within the national science community and also benefit from more tenured, permanent, and higher paying positions (National Science Board, 2009). Within this community, females are more likely to work in biological and medical sectors. These trends suggest that role models for females in science are not as prevalent and far-reaching as male role models, and are limited to work in biological and medical fields.

Kessels (2005) explored the characteristics of prototypical constructs of scientists in a study with eighth and ninth graders from Germany. Kessels' research in the context of U.S. classrooms is relevant because similar gender trends that occur in the United States are found in the larger Western science community that includes European Countries (Palermo, 2008, She Figures, 2006). Kessels used quantitative design and correlational measures to evaluate 200 students' perceptions of popularity (self and peer), self-ability, school subject preference, and gender prototypes for music and physics. The findings suggested that the more similar a student's self image was to his/her prototypical image, the stronger that student's liking for that subject. The prototypical images revealed a congruency between male and female students, who value physics as a male domain and music as a female domain. Also of interest is the finding that males in this study who played music did not consider themselves less popular because of their musical interest, while females who liked physics considered themselves to be viewed as less feminine and less popular overall.

The issue of popularity brings up another variable within the domain of identity. If an individual is to experience social isolation and receive negative attention from their peers based on their participation within a subject, then that individual could be less motivated to continue their intellectual pursuits. In the case of feminine identities preferring physical science, there is a social obstacle to overcome, that males who are developing a science identity are less likely to encounter. Kessels' (2005) study proposes a reason for why feminine identities are less likely than masculine identities to pursue studies in physical science in secondary grade school, but also suggests a reason for why females with more masculine identities could be attracted to physical science. These features of science identity researched by Kessels represent a binaristic approach to gender within science identity, which educators should be careful to assume when designing science curriculum and responding to social norms within the school.

Kessels' (2005) strengths in this study included a satisfactory number of participants and the use of highly regarded questionnaires and data suitability tests. Her factor analysis revealed a significant correlation between the variables of gender, school subject preference, and popularity. While Kessel's data is valid in certain ways, it could be improved. For example, little is known of the socioeconomic demographics of the participant population. This factor reduces the transferability rating for the results. It would also be advantageous to see a wider breadth of gender perception, rather than be limited to a music/physics dichotomy.

A qualitative study by Hughes (2001) is grounded in research like Kessels (2005) that suggests physical science is perceived as a masculine venue while biology attracts a larger feminine contingency comparatively. In addition to gender however, Hughes included ethnic variables as well in her research. Hughes conducted 60 interviews in an England high school, and allowed the students to be interviewed in self-selected pairs to increase their comfortability. In her analysis Hughes prioritized interviews in which students explored the complexities of gender and ethnic identities.

Students' comments during the interviews supported sociological patterns within a heteronormative, hegemonic middle-class, male perspective that view masculine knowledge as rational and authoritative and feminine knowledge as sensible (Hughes, 2001). Certain male participants viewed physics as a necessary knowledge needed to advance in the professional arena, while female participants viewed physics as containing useless details. Females throughout the study were more likely to be interested in biology than other sciences, as its core content contains information associated with living organisms and processes. Ethnic variables were also exposed in the responses from a Vietnamese participant. Her goals for science achievement were inspired both by the challenge of succeeding as a minority and by fulfilling the prototypic academic benchmarks expected of her within her culture.

Hughes' (2001) findings benefit from frequent member checking and critical analysis of data. She describes student subjectivities substantially, giving full recognition to the participant's background, influences, culture, and personality. After narrowing down the interview pool, Hughes featured only six interviewees. This small sample size is revealing of the essentialist tendencies within science education, but leaves out potential cases where essentialism tendencies are not in operation. Hughes lacked persistent observation and prolonged engagement with her participants, which poses a validity issue concerning transferability. In addition, allowing students to be interviewed in pairs could yield different results that are more peer-influenced than individual interviews. This is especially important considering the sociological nature of Hughes' dialogue material and the complex nature of identity.

A large study was conducted in Arizona that implemented a one-day program designed to enhance math and science career development for female students of minority and low socioeconomic status (Kerr & Robinson Kurpius, 2004). The intervention program titled TARGET worked with 502 girls, ages 11-20, from 45 different schools. Girls were selected based on a series of risk factors, which included poverty, low self-esteem, unsafe behaviors, and poor family support towards career development.

TARGET was a one-day program that hosted the participants on a college campus. During the intervention the participants completed career and values inventories, engaged in discussions concerning their values and barriers they could face en route to career development, imagined a perfect work day ten years later, received a campus tour and individual counselor guidance, and were formally recognized for their participation in TARGET during a graduation ceremony. After finishing the program, the participants were assessed twice more, once after three months, and once after two years. While the intervention began with 502 students, but only a small number of participants completed all assessment periods.

The researchers (Kerr & Robinson Kurpius, 2004) found that in the three-month follow-up, participants career searching behaviors had increased, had a higher sense of self-esteem, and greater confidence in the future. These variables were measured using various inventories and questionnaires such as the Rokeach Values Inventory, Career Behaviors Inventory, Educational Self-Efficacy Scale, and the Rosenberg Self-Esteem Scale. While Kerr and Robinson claim to have seen positive effects of TARGET, there are validity pitfalls that need to be addressed. First, the lack of participant continuity throughout the assessment periods created a much reduced sample size and therefore, the transferability and effectiveness of this program cannot be adequately evaluated. Second, the participants represent an at-risk, adolescent population that involves frequent dynamic and challenging life experiences.

With TARGET being a one day program that focused on questionnaires and mentioned little of meaningful discussion concerning student's experiences, personal histories, and identity issues, the intervention lacks the time and motivating substance that could have a deeper impact on the participants to pursue math and science careers. That said, creating multiple opportunities for students to imagine and project future identities and insert them into secondary classroom work is congruent with the nature of identity growth. This requires situations where students can consider future selves within classroom learning moments. Perhaps TARGET could be more successful if this experience was integrated with classroom curriculums within the participating schools, where students could continue to consider themselves in terms of career development and their own potential that is thus recognized.

The research by Kessels (2005) and Hughes (2001) identifies barriers that feminine genders struggle to overcome in the science classroom or accept to be culturally or biologically normative. Their findings suggest a need for a deconstruction of gender prototypes within the classroom and the need to provide prototypical models from across the gender spectrum. With this awareness, science teachers should work to create science curriculum that offers access for students of non-masculine genders and non-Male sexes to develop a science identity. Research by Kerr and Robinson Kurpius (2004) with the TARGET program represents a move towards creating school curriculum structures that offer students the opportunity to develop a science identity. I recognize that the issue of gender in science education and identity development is highly complex and requires the constant attention of educators within a critical pedagogy format. Taking into account how and why gender structures within the science community limit the development of science identity for many students can help teachers and researchers construct bridges for spanning these pitfalls.

Connections Between Students' Experiences and Conceptual Understanding

As discussions in this paper have touched upon the connections between students' worlds and their motivations towards developing a science identity, the following research will advance these discussions into more specific domains.

In urban environments, students' experiences with science might often revolve around technology and science-applied mechanization of instruments and industry, particularly computer technology. With limited interactions with natural spaces and wilderness areas, students are forced to learn about ecological concepts through various literacies, such as text, video, and story (Louv, 2005). How students conceive ecological relationships in urban settings is the subject of research by Burke (2007).

Burke (2007) collaborated with a veteran 5th grade teacher to design a curriculum that involved connecting urban students with natural spaces, observing their findings, and writing a fictional narrative about a non-human creature and their means of survival. The classroom population was composed of 20 African-American students, one White, and one Latino student. Ninety percent of the class received free or reduced lunch, representing a clearly defined status of poverty within the community. This research was guided by ethnographic methodologies, and involved recording field notes, interviews, and participant-observations. Before creating the curriculum, the context of the classroom and students was analyzed in effort to create a culturally responsive curriculum and design. One of the main implementation goals was to personalize and localize the curriculum by connecting it to the students' lives and experiences outside the classroom. Through this research, how students' non-congruent identities influence science conceptual learning is better understood.

The curriculum consisted of four inquiry lessons that explored the ecosystems within the schoolyard and the local community. These activities involved students analyzing various cross-sections of dug soil and identifying and recording their observations, identifying natural resources on walks around the neighborhood, and constructing terrariums using two-liter bottles, natural materials, and organism from the schoolyard and local pond. The final activity required students to write a story following the narrative framework: "Somebody (the main character) Wants (the motivation) But (the conflict) So (the resolution)" (Burke 2007, p. 362). The students applied their understanding of various organisms, processes, survival needs, and resources they learned about through the previous exploratory activities.

The resulting narratives were combined elements of ecological conceptual learning and autobiographical accounts of student' own personal lives. Interestingly, students often seemed to model their non-human characters after their own identities and challenges in life, revealing both their levels of conceptual understanding, but also possible details about their own lives and ecological limiting factors. Students often used characters that were in a constant state of starvation, or who were not allowed to have any food, reflecting their own personal struggles in securing meals. Some characters dreamt of having good living standards, while some were homeless in which case a hole in a log was used as a makeshift home.

This curriculum was revelatory of students' perceptions of their environment, and the negative confluences of environment and social depravity; vacant lots used as dumping grounds, the smell of landing jet plans nearby, and the insecurity of the habitat due to gangs and violence (Burke, 2007). In this case, students' identities existing in a physical domain of danger, food shortage, and homelessness were primary features in their narratives. Influenced by their personal stories, students connected with the survival-based aspects of non-human organisms versus a possible natural abundance that maintains a relative balance between predator/prey within an ecosystem.

This research (Burke, 2007) can also be perceived through a discourse lens, in which the inquiry activities are used to stimulate discussion about ecological survival and maintenance in terms of both the natural organisms and cycles and the ecological implications students face in their personal lives. Dialogue of race and privilege can now also be introduced through a context of ecology, exemplifying how organisms within an ecosystem develop relationships with each other based on available resources and population histories. A major challenge postulated by Burke (2007), is directed towards science teachers in presenting and understanding science in conceptual terms, rather than as a series of discrete facts. This can be interpreted to suggest that as students share personal narratives and information with a discourse community, the teacher must be able to understand this information and weave it into a correct and correlating conceptual understanding.

In addition to creating an accessible out-of-class context for students to integrate their personal histories and essential characteristics of their identities, focusing on in-class environment and the use of hands-on science activities can provide for significant conceptual restructuring and understanding as well (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). Vosniadou et al., provide research that focuses on the construction of learning environments that foster science learning. This research is based on the conceptual learning approach, which advocates that science learning does not happen through an enrichment of empirical facts, rather it occurs through the reorganization of existing knowledge structures and in-depth inquiry into specific conceptual domains. The identity-related nature of this study entails introspection into a domain that students are often not familiar with, a revelation of our physical, kinesthetic knowledge that has enabled orientation with our surrounding environment and the ability to interact with that environment in physical ways. Despite the success of this knowledge in allowing us to walk, run, push, pull, drive cars, etc., the researchers claim that conceptual physical science operates on foundational laws that are objective of our physical memory and conceptual understanding of how the physical world operates.

The structure of Vosniadou et al., (2001) quantitative/qualitative experiment included an experimental and a control group, both of fifth grade students, ages 10-11. Both groups studied the nature of mechanics over the course of eight weeks, however, the experimental group worked with a curriculum that was designed by the researchers' experimental team and was also taught by one of these experimenters in the presences of the classroom teacher. Test results indicating statistically significant success rates for the experimental group were analyzed through pre- and post-test variables, with both groups receiving the same pre- and post-tests. Qualitative analysis of discourse, videotape, and interviews revealed a deeper and more complex classroom discourse in the experimental group in which students engaged in dialogue that demonstrated scaffolding and connected with the curricular concepts.

The experimental class followed a curriculum that emphasized constructivism, collaboration, and participation in meaningful activities. The class was divided into five groups of five students each, which created a learning environment conducive for small group discussions, experimental work, and large group discussions. The experimenters gave much thought to the sequential design of the curriculum that addressed the constructive nature of mechanical concepts, giving importance to possible misconceptions students might have. For example, before exploring reaction forces, the misconception that force is exerted only on moving objects was reconstructed. The experimental class traverses from prior knowledge prompts, to the introduction of a new concept, to conversation and debate of a new concept, to interacting with the concept via experimentation, to close with a brainstorming session of other examples that follow the conceptual principles just learned. Also, the structure of classroom dialogue within the experimental class was quite different from that of the control group. The former was characterized by more complex discourse, a multifaceted non-uniformity, and explicative question prompts, whereas the latter contained mostly straightforward exchange that revolved around simple question/answer prompts and relatively unrelated questions.

The strengths of this study (Vosniadou et al., 2001) lay in its triangulation of data between quantitative variables, qualitative analyses, and guided research. The course length of eight weeks is an adequate amount of time to implement an experimental curriculum, record data, and evaluate its affectivity based on students' test results and qualitative variables. This research describes the benefits of a constructive-based discourse community, hands-on experimental activities, and teacher-guided instructing that emphasizes conceptual understanding. With these structures in place, students engage in multiple experiences that allow for identity development. Through the social nature of the experimental group's activities, students are able to practice science language in a supportive environment. The emphasis on prior knowledge encourages students to construct science concepts from their own past experiences as well as those from their peers.

The last two research examples (Burke, 2007; Vosniadou et al., 2001) suggest an increased conceptual understanding through the construction of a curriculum that includes students' tactile and kinesthetic experiences in the learning design. The following research study details the process of how curriculum can be successfully designed under student guidance, and is inclusive of community, family, peer, and popular culture funds of knowledge resulting in the creation of a hybridized learning space within a science classroom (Barton & Tan, 2009). Barton and Tan build from Discourse theory (Gee, 1996), situated learning theory (Lave & Wenger, 1991), and various composites of identity, minority, and linguistic research. Their study is guided by theory supporting the exercise of students' out-of-class identities, cultural identities, and societal identities.

After conducting previous work studying the merging of girls' social worlds with their science worlds, they discovered that a unit on food and nutrition was especially engaging. In this study, Barton and Tan (2009) collaborated with a sixth grade teacher, Mr. M, and five students (four females and one male) to construct a food and nutrition unit that created opportunity for students to apply various aspects of their lives to their science learning. This particular site was chosen for this study due to its location in a large urban center, its low-income status, and minority population (55 percent Hispanic, 45 percent African American). The Inquiry School (TIS) was established in 2004, and offers a slightly science-focused curriculum to middle grades, in attempt to relieve the population pressures on the nearby K-8 school. Details of the neighborhood were included in the methods to support the large cultural influences and communities (Dominican Republic, Puerto Rican, African American) of which the students are members.

Over the course of the nutrition unit, students completed four assignments that included a comprehensive nutrition guide, a healthy snacks poster, explanations about the snacks, and a healthy snack activity sheet. To complete these assignments, students ventured into the community accessing local and family history, local commerce, and community/social nutritional trends. They were excited to be able to represent their families in terms of recipe and food sharing. Inside the classroom, Mr. M created a discursive space that allowed for students to describe their projects in terms of a personal and cultural narrative. As the unit progressed, students became familiar with healthy and unhealthy foods, experienced strong feelings of pride and comradery in sharing their identities in a safe environment, accessed a science identity to understand nutrition, and were able to critically analyze the nutritional foundations within their community and local food establishments. The classroom became a hybrid space that increased students' representation in discussion, and physically represented home spaces and community spaces, complete with personal artifacts and cultural icons. In terms of actual grades and completion of assignments, Mr. M declared that this had been the most successful unit of the year, with all students completing assignments and most students receiving their highest marks of the year (Barton & Tan, 2009).

While Barton and Tan (2009) present evidence that suggests students' improved schoolwork and engagement was do to curriculum co-planning with students, allowing students access to their cultural funds of knowledge, and transforming the classroom space in culturally stimulating ways, there is little mention of scientific concepts actually learned. The educative focus seems to have been placed on caloric content and the use of the food pyramid, and did not appear to analyze the actual nutritional content of foods or connect them with the physical health, systems, and processes of the human body. To what degrees did the students consider themselves engaging in the scientific process and participating in a science-specific discourse? A culturally relevant science pedagogy must create spaces for students to display and communicate with their cultural identities, while also learning science domain practices and language. This topic of contextual shifting will be further discussed.

Transitions: Competency, Valuation, and Conceptual Congruency

This section will begin with research focusing on kindergarten students, one of the youngest science learning populations (Patrick, Mantzicopoulos, & Samarapungavan, 2009). This is especially pertinent to identity research as this time period represents one of the first encounters students have with a science teacher within a classroom. This quantitative/qualitative study reflects motivation levels for girls and boys in terms of their beliefs about science and their competency.

There were 162 kindergarten participants involved in this study, representing three different schools in a low-poverty, ethnically diverse area, with over 70 percent of the students receiving free or reduced lunch. The experimental variable referred to what type of science education the students received. In one school, a typical kindergarten science curriculum was taught. The other two schools participated in the Scientific Literacy Project (SLP) for either five or ten weeks. The regular curriculum focused mostly on mathematics and reading and only taught a couple of science units, mostly through storybook or art instruction. The five-week SLP group engaged in two science lessons a week lasting 60 minutes each, and focused on living things and the butterfly life cycle. The ten-week SLP class explored both living things and marine life. Several measures were used to determine students' motivation and competency levels following the interventions.

The Puppet Interview Scales of Competence in and Enjoyment of Science (PISCES) developed by one of the researchers, used puppets to help students identify their own levels of understanding. Students selected from one of the five ethnically diverse puppets, and agreed with one of two opposing statements represented by two identical puppets that the student had previously chosen. Other criteria used were the Perceived Science Competence scale, the Science Liking scale, the Science Process scale, and the Perceived Marine Life Knowledge scale, which was only administered to the typical and ten-week SLP groups. Qualitative interviews with all teachers revealed that they tried to work science as best they could into their curriculum units.

Results were obtained through a 2x3 (gender, kindergarten group) multivariate analysis (MANOVA) of the survey data, that significantly showed (with a $p<.001$) students in the ten-week SLP course maintained a higher perceived science competence and science liking. Students in the five-week SLP had means slightly below the ten-week group, but still scored higher than the regular kindergarten group. The only gender difference was found in the regular kindergarten group, where boys maintained a stronger liking for science than girls did. During the experiment students also completed narratives during an interview that revealed much about their obtained science vocabulary and conceptual understanding. Both SLP groups used a more science-related vocabulary, giving descriptions of relationships and organisms they had learned about in their units. SLP lessons involved the use of hands-on materials to learn about a subject. Activities were organized so that the nature of the science process, including such skills as questioning, observing, hypothesizing, and testing, was practiced.

Before claiming that SLP-style programs implemented into kindergarten or early school curriculums are solely responsible for an increase in science competency amongst students, this research (Patrick, Mantzicopoulos, & Samarapungavan, 2009) did lack some controlling variables, of which the researchers recognized. First, pre-tests were not administered to the groups of students. Also, little description is made of teaching styles of the participating teachers, and how their curriculums were correspondingly constructed. Nonetheless, controls for gender and ethnicity were present, and many cautions were taken in measuring students' levels of competency and motivation. This research could also become longitudinal, exploring how students' science liking and competency change as they develop through grade school. Inviting students into the science domain at early ages, in ways that mimic techniques and concepts that will continually be practiced through the years seems congruent with discourse theories of practice and contextual shifting, resulting in a further developed science identity.

While teachers recognize various ways in which students develop between school years, accounting for maturity, ability to contextually shift, and diversified experiences, students might not encounter distinctly aligned progressive curriculum as they advance through their education (Anderson, Jacobs, Schramm, & Splittberger, 2000; Braund & Driver, 2005). This incongruency between experience and curriculum is not helpful for students in their development of a science identity as standards, expectations, and views of science are so radically independent of the perspective corresponding teachers hold. The following research explores the transitional components between school years that could affect how quickly students adjust to newer science contexts, and more readily integrate their previous gains in the development of their science identity.

Braund and Driver (2005) conducted a quantitative/qualitative study that identified levels of congruency in science expectations and development between primary and secondary school. The keystone inquiry under arching this research is how students perceive the application of practical science work in between the ages of 10 and 12 (the division between primary and secondary school). The main instrumental criterion employed was a questionnaire which contained six open-response type questions. These questions asked students to comment on differences between primary and secondary school science and remark upon their general presuppositions of science. Participants were drawn from five primary schools and three secondary schools, during the month of November, having allowed secondary students time to settle into their new subjectivities as secondary students. In total, there were117 year six (primary) representatives and 105 year seven (secondary representatives).

The first question asked students why tests, investigations and experiments were necessary tasks in science education. Nearly 10 to 25 percent more year six students thought these practical science tasks were influential in obtaining job as a scientist, helping with future learning, and in applying skills to carry out science. This suggests optimism amongst year six students that science education is a beneficial and necessary pursuit, and will also become more engaging in secondary school. In the second question, students were asked what would be, or is the same between primary and secondary science. Again, optimism seems to be present in year six as they believed year seven science would employ the same basic approach. However, only seven percent of year seven students, who were already two months underway in their year seven studies, thought that year seven science employed the same basic approach as year six science. Rather 23 percent of year seven student said nothing is the same, while zero percent of year six students thought nothing would be the same (Braund & Driver, 2005).

More year six students also thought that in year seven, students will use better and different equipment, work will be harder, more advanced and dangerous, and they will conduct more work in a laboratory or specialized area. Year seven students differed in that they said year seven involves more experimentation. The authors comments on the fact that year seven students feel like the work is not harder or more difficult than in year six, reflect a potential decrease in challenging tasks at the beginning of year seven (Braund & Driver, 2005).

One criticism of this study (Braund & Driver, 2005) could be given the potential for individualized teaching practices and the dissemination of particular philosophies regarding science practice and the use of laboratory instruments, the sample size was not large enough to reflect significant trends within year six and year seven populations. Regardless, it still seems that both year six and year seven students maintain a positive attitude towards science, enabling science identity forming thought to manifest. Another criticism concerns the structure of the transition itself. The year six students were not only advancing one grade level, but they were graduating to a entirely new school. They were also the top class of the primary school while the year seven students were now at the lowest rung in the secondary school. Thus there are many reasons unrelated to science class that could account year six students' optimism and the year seven students' steadfastness. Also, year six students were being asked questions concerning there future, while these same questions applied to year seven students' present experiences. It would be interesting to see research that identifies trends indicative of transitions between early secondary years and later secondary years, as this time period seems to see significant divisions in students who successfully develop science identities and maintain positive science perspectives.

This section provides a couple examples of how science identity shifts during transitional levels within young students' schooling experiences. In the first case, there is some evidence that suggests science identity may begin to form in major ways during a small amount of time in Kindergarten, depending on the content and duration of the curriculum. During middle school transitions, Braund and Driver (2005) discovered a particular optimism experienced by incoming middle school students towards science learning. Year seven students exhibited a less optimistic attitude and felt that their studies covered material they had learned the previous year. This research is significant because it reveals science identity to be contingent upon projected ideas students have of science identity as well as how students are generally affected during transitions into a new school and a new school year.

Discourse Community and Contextual Shifting

A specialized and unique language accompanies a specific domain. This discourse is necessary for participants to understand and communicate the corollary knowledge associated with their domain. Science discourse involves language that is often regarded by students and professionals as a 'foreign language'. This presents a great barrier for students in the process of developing a science identity. If students cannot speak in science discourse, then their ability to enter a science domain and participate with a science identity is marginalized. In a science classroom setting, developing an ability to communicate in scientific discourse should be a primary goal for the classroom community. Within the past decade, much theoretical and experimental research has revealed the deep connections between identity, discourse, and scientific achievement.

Roth (2008) offers a perspective on discourse that includes concepts of hybridity and language learning, to help encourage scientific language acquisition. Roth's expert analysis of science language learning is supported by well-described student scenarios and grounded theory. Roth's participants include ninth and twelfth grade physics students from a small, rural Canadian high school who speak English or French, and a seventh grade science students who are English speakers learning Science in French.

The research inquires about how the development of a learning ethic guided by diaspora and difference can create a symbolically non-violent, science-learning environment for all students. For Roth (2008), diaspora refers to the challenging aspects of immigration a student faces he/she moves to a new country. Roth seeks to recognize and encourage the normality of diasporic experiences in order to develop teaching pedagogy that successfully bridges cultural and linguistic domains to a science domain.

In several examples, Roth (2008) elucidates how in their attempts to learn science and complete various classroom activities, his students often hybridize their first language with both the language they are learning science in and the science language itself.

Students are thus engage on multiple linguistic levels, producing a product that is a 'creole' compilation of their effort and linguistic capabilities. Roth's experimental teaching approach contains many elements of language learning programs. Regarding science as a foreign language, Roth creates activities and allows students to piecemeal language to construct an overall, unified meaning.

In an effort to acquire a second language, such as a science language, Roth (2008) bases his experimental pedagogy on the premise that proper acquisition does not occur by merely translating the new language into the learner's previous way of understanding, but rather allowing the learning to translate their new experiences into a combination of new and old language. This represents an experiential approach that encourages identity hybridization through the exploration of differences, versus more traditional approaches that emphasize homogenous experience and language to enforce identity transformation. Much of Roth's constructive pedagogy seems based on his personal experiences with diaspora, migration, and foreign language learning.

Roth attempts to create a science discourse community that allows all students to participate, whether or not that have complete capability at speaking appropriate science language. Theoretically, this creates a more accessible science curriculum by inviting students to use their previous knowledge and identities to interpret their new science learning. One challenge to this linguistically malleable pedagogy is the potential for students to interpret this as a de-emphasis on correct science language, both written and verbal. At some point, a specific discourse community, such as a classroom, should help students bridge their learning to a larger science discourse community that they also participate. While being able to communicate in various science discourse communities will help students develop a stronger science identity, but students must able to shift identities from science class to other curriculum subjectivities and vice versa.

One term used to describe this process is contextual shifting (Reveles & Brown, 2008). In this research, Reveles and Brown conducted their ethnographic case study in a third grade and a fifth grade classroom. Their goal was to identify strategies the participating teachers used which helped students shift into identities conducive to a science discourse community. Data was collected using videotape recordings, field notes, science projects, and interviews with the participating teachers and students. In their analyses, Reveles and Brown used a sociolinguistic framework to code conversations into common discourse groups.

Similar discourse development techniques were employed by the teachers which emphasized academic and science identities through investigative and inquiry based experiences. These activities encouraged students to connect common 'everyday' language and scenarios to science language and concepts. Both teachers worked to develop a science curriculum that presented science as on ongoing part of their identities, which is built upon prior experiences. Thus, students worked on activities that developed observation and experiment skills, centered on everyday science phenomena within their lives.

A similar study explored the hybrid discourse in a science classroom of recently immigrated Haitian students (Ballenger, 1997). The concurrent project titled Cheche Konnen Project, which means 'search for knowledge' in Haitian Creole was concerned with enabling students to learn science in a bilingual setting. The study involved discourse analysis of a particular series of dialogue exchanges regarding the nature of mold. The two participating teachers in this case study co-instructed one classroom of fifth through eighth graders. Sylvio, the seventh and eighth grade specialist was Haitian and a Haitian Creole speaker, and after watching a video of his students in another science class successfully debating a scientific topic in Creole, he allowed his students to speak Creole in his class. This study is to shed light on the debate of whether informal, everyday language can benefit science discussion and act as a consistent invitation to develop a science identity.

One observation in this study made note that in allowing students to speak in everyday dialogue and include their personal experiences in science discourse, there was relevant impetus for students to continue to explore the topic in scientific terms. The topic 'mold' began as a conversation based on students experiences with mold in their homes, and eventually led to a shared desire to design experiments that would test their hypotheses and observations. Also of noted importance, was how this discourse led to exposed misconceptions about what happens as food ages? The students held a common, non-scientific belief that when cheese and mango were left together for some time, a mouse would be produced. This belief led to an exploration of the concept of mold and how organisms can benefit from food left to the whims of bacteria.

Further discourse analysis began to reveal how social identities were played out in non-academic classroom discourse. Some students argued their ideas in disregard to scientific thought. Moral characteristics were also intermeshed in students' arguments, and the prevention of mold was used to define certain student's moral valuation of cleanliness. However, rather than accept these declarations as the scientific norm, the teachers facilitated discussion that led to student-designed experiments testing the stated hypothesis. Thus, student emotion, identity, and prior knowledge were used to create scientific curriculum, and in doing so engaged the class in much more fruitful ways than a typical, pre-formatted curriculum design would have. As peer discourse developed and became normalized, the teachers began to assume roles as facilitators rather than beholders of knowledge. Instead, students' queries demanded attention and took on social authority that invited students to enter on a more social-friendly domain, rather than a teacher-student academic domain.

While these three previous studies (Roth, 2008; Reveles & Brown, 2008; Ballenger, 1997) recognize the necessity for students to speak in their native tongues when interpreting the foreign language of science and exercise their social and cultural identities, the intentions and perceptions of science are not necessarily being addressed. Are these students realizing their science identities and feel challenged and motivated to learn academic science discourse, or are they simply interpreting science as an extension of their everyday experiences and dialogue that does not require the formation of a specific identity?

In order to effectively integrate contextual shifting skills into science curriculum, science educators must understand how students perceive a science context in relation to their other contextual discourses. An important question to be asked of students concerns what makes science a unique context. From this information, educators can determine potential barriers and bridges their student's might face that effect their ability to develop a science identity. Brown (2005) examined how individuals constructed and perceived science identity in a group context. His qualitative ethnographic methods sought to uncover biases, beliefs, attitudes, and opinions students held towards science.

In Brown's (2005) study, he divided 29 ninth through eleventh grade students into groups of four or five, designed to provide a variety different socializing contexts. Participants made up a diverse group, and included Cambodian-American, Mexican-American, African-American, Vietnamese-American, El Salvadorian-American, Latino-American, Chinese-American, and European American. Over 50 percent of the large student body in the high school lived below the poverty line.

As a whole, students identified science class to be unique experience based on laboratory work, measurement activities, and specific types of writing activities. They believed that hands-on activities improved the learning experience, increased interest, and furthered understanding. One student described that constant note taking is not as beneficial as hands-on activity. Students also believed that hands on activities would better prepare them for participating in science when they are older or in college.

When asked about scientific problem-solving students rarely included themselves in the community of scientists. However, students had sophisticated opinions about how science was practiced and known. Students considered scientists to be individuals who were interested in science and considered it their vocation "...to study a certain subject and use big words” (Brown, 2005, p. 105). Scientists were described as being detailed, laborious, and exhaustive in their pursuit of information. Some students recognized a sociocultural relationship amongst scientists and valued science as a process of information gathering, trial and error, discovering and rediscovering. Despite students' understanding of how science works and how scientists conduct themselves, they did not see themselves as scientists or sometimes even potential scientists.

In terms of scientific discourse, students described science as containing double meanings and laden with social burden reflecting a scientists intelligence. Science knowledge contained a depth that was not common to their typical discursive behavior. One student was aware of the somewhat universal nature of science language and how the big words functioned across the globe and that scientific discourse is designed to break down, organize and make information clear. He said, "Science has its own little slang to it. It's like once you learn science in here; you can't take it to every class and just talk like that. 'Cause most people wouldn't understand it" (Brown, 2005, p.105). Another student spoke to the nature of slang and science language that "…is totally different; in other classes like in English they teach us how to talk in English. Our problem is we talk that slang, they gotta correct it from now and then, when they hear it. We can't put slang in science, it isn't no slang that can be said about this stuff" (Brown, 2005, p. 113).

Some African Americans considered that African Americans lacked focus and discipline, motivation, and self-efficacy needed to succeed in science. They said that African Americans were more interested in quick money and getting a good job right after school. These participants went on to say how White people can stay focused and get right to the point, not as distracted.

The research (Roth, 2008; Reveles & Brown, 2008; Balenger, 1997; Brown, 2005) in this section suggests that the development of a science identity is aided by a teacher's ability to create a supportive science language-learning environment. This includes designing curriculum for English language learning students that allows them to integrate their first languages into their writing and speaking. The ability to shift between linguistic constructs is an important skill when developing various identities. Since science language is specific and complex, teachers must be able to help students access their science identities as they move between science class and their other classes. The more often teachers can create opportunities for students to realize connections between the science curriculum itself and between a science identity and a student's other identities, the more successful a student will be developing a science identity.

Metaphorical, Causal, and Hybrid Discourse

A further look into discourse practice considers a few styles and interventions that have been analyzed in the science classroom. As science discourse within the classroom emphasizes learning science through talking science rather than reading and writing science, the following studies analyze the affectivity of specific discourse formats, teacher interactions, and how individual student subjectivities can be included in the classroom and scientific community discourse.

One variable in the development of science identity that has yet to be discussed is the degree to which students understand the nature of science, often symbolized in terms of age and/or competency. For students of middle level sciences often grade levels five through eight, perhaps they have participated in supplemental elementary science units, or if not could be processing science concepts for the first time. The previous experiences students have with science has a great effect on the development of their science identity. The following analyses of these further discourse studies will inquire further into hybridization and multiplicity of science language with other various forms of discourse of which students have adapted.

Two particular formats of discourse of interest are causal and topical. Causal discourse style refers to the presentation and discussion of information in which concepts are linked and connected. For example, in a science lesson on the nature of tides, studying tidal patterns in relation to lunar and solar patterns, and seasonal and hemispheric characteristics unifies tidal concepts and includes astronomy, ecology, and geographical perspectives. Topical discourse is incremental in nature, often segregating subjects into sections to be taught sequentially, such as chapters in a textbook. Woodward (1994) reveals a clearer understanding of the individual affectivities of causal and topical discourses in a quasi-experimental setting. By choosing participants at the eighth grade level, Woodward attempted to control for prior-knowledge and understanding, allowing discourse style to be a primary variable in student understanding and retention of the material. Two earth science classes participated, comprising a total of 46 students. Within each class, students were divided into two groups, causal and topical. Two pretests were administered to students prior to the beginning of the experiment which tested for reading and science capabilities. On these tests, all students scored average or slightly above average, which the researchers interpreted to mean that the students were all of similar capability, thus reducing potential future performance inequalities.

During the first four weeks of the experiment, all students were introduced to physical science concepts in a causal discourse format. Once a basic background of information was determined, students were then randomly assigned to either a causal or topical group. For the following six weeks the students learned about convection and the related geological and meteorological cycles. Halfway through the six-week period, the teachers switched classrooms so that the causal teacher then taught in a topical discourse style and vice versa, to further isolate the discourse variable and reduce the affects of teacher persona and individual styles upon student learning. During the causal class, students were presented with the concept of convection and how various related earth processes were connected to this phenomenon. They often worked with diagrams and video clips that focused on the larger picture of convection.

Students in topical group instead were taught in a sequential format that reduced the convection-related processes to individual phenomena, and often learned about a specific pattern in terms of its commonly known system. For example, a lesson on tornadoes was taught with regards to weather, climate, and pressure systems, and did not focus as much on the causal variables for what determines specific weather patterns. Both groups used similar modes of literacy for equal amounts of time, including video and slide mediums. The control of temporal variables, teacher selection (though one of the teachers was the researcher, both were experienced public school teachers familiar with course content thereby reducing experimental misdirection), and assessment provides a solid foundation for understanding the effects of the discourse formats.

To evaluate effects, the researcher administered four tests to all students. The first test covered the first four weeks of the course, where both groups were taught in causal format. This test was followed by a more comprehensive earth science test which covered the final six weeks of the experiment, an applications test, and a key facts test. Students in the causal group scored higher on all tests. A maintenance test was issued some time after the unit, and students retained nearly identical mean scores as they achieved during the initial testing phase. The researcher found these statistics to be strongly significant in correlating with both instructional methodologies.

This study is significant in that the experiment was conducted daily with students and with effects measured by four separate tests and two additional maintenance tests. Unlike other experiments of this type where data is compiled through infrequent audio recordings, limited observations, or a shorter time period of intervention, this experiment was continuous and designed to control for the instructional methodology variable. It could be argued that students in the causal group were better able to apply characteristics of science identity, which involves learning and thinking about concepts as whole systems in multiple literacies. This enables students to internalize a potentially abstract concept through its connections to more relevant features and phenomena. Students in the topical group were forced to think in isolated terms, tackling one process at a time, unaware of greater conceptual connections and relevancy to their lives.

Classroom discourse can vary in different forms depending on whether discussions are teacher facilitated or conducted in small student groups. Thus, the context which accompanies a discourse can have an impact on student participation and overall comprehension. With causal concept discourse students are able to connect various parts to better understand the driving mechanisms of scientific processes and forces. Another area of discourse being studied explores the use of metaphor during science classroom discussions. This revisits the controversy of everyday language and experiences students can relate too versus speaking in a critical science tongue that favors advanced vocabulary and precise definition. While the use of metaphor creates opportunities for students to connect a scientific concept with experiences that compose their personal identities, it is a concern that metaphor can confuse, simplify, or misrepresent the scientific concept it intends to make sense of.

Working in northern England, Cameron (2002) conducted a case study which explored the nature and effectiveness of using metaphor in science discourse. Cameron supports her study with research that describes the positive effects on student learning and challenges students encounter when connecting formalized science concepts with abstract non-science related objects and occurrences. There were two situational contexts Cameron analyzed, one being how students interpret metaphor in small group settings, and the other being how students interpret metaphor and increase their understanding of science concepts during teacher-led discourse.

Participants in this study consisted of students aged 9-11 years old in a rural primary school. Thirteen hours of discourse data was recorded over a period of two months. Data was then divided into two sets, with one set describing think aloud small group interactions between students based on a metaphor prompt and another set describing a teacher-led whole class discussion on geology. Cameron (2002) analyzed the data with a sociolinguistic perspective, in attempt to determine if metaphors were creating understanding or misinterpretation of the science concept, which in the case of the peer interactions, was the function of the ozone layer. Students were given the metaphorical terms 'blanket' and 'shield' to describe the ozone layer. Cameron noticed that students were using the metaphors to describe the functions of the ozone layer but due to a limited conceptual knowledge of the metaphors, students were unable to connect the metaphors to accurately describe and define the ozone layer. This situation could also be viewed as a playful challenge, in which students are attempting to connect an abstract scientific concept with familiar words and images. The author suggests that the spontaneous conceptual structuring of the metaphorical images is severely influenced by intense imaging via television, leading to a strong visual application of the metaphors, but potentially reducing the abstract, non-visual details of the ozone layer (gases, function, harmful and beneficial effects).

Cameron (2002) found a more positive impact of metaphor on conceptual learning during the teacher guided discussion. Rather than working from a text, the students were engaged in discussion which enabled a rapid and reactionary exchange of ideas and (mis)conceptions. This whole-class discussion was based on the nature of igneous rocks students had collected on a recent field trip. Throughout the discussion the teacher used the metaphor of runny butter to describe molten rock within a volcano. Unlike the small group discussions, correct interpretations of the metaphor was directed by the teacher by explaining in what context runny butter should be considered to describe the nature of molten rock. By asking the class if they were familiar with melting butter in a dish in the microwave, the teacher was able to help students recall a specific instance in their lives that helped them understand what happens to rock inside a volcano. Occasionally, students would suggest an interpretation of the metaphor or a new metaphor that they thought might be analogous to the concept of molten rock, but was incorrect. Understanding their explanative thinking, the teacher was able to identify the misinterpretive features and reguide their thinking to a more correct interpretation. This process also allowed the class to practice concept attainment by identifying examples and non-examples of the scientific concept.

The primary contribution to identity research is Cameron's (2002) application of the philosophical construct of alterity. In the context of science discourse, specifically metaphorically speaking, alterity represents the ability for participants in a classroom to understand one another and 'conceptualize their state of mind'. As a metaphor symbolizes an intention to connect a concept to various agents, it is often a teacher that assumes this role as he/she has a developed ability to understand the minds of his/her students. Thus within Cameron's context of metaphor, alterity could also be used to describe how well a stated metaphor accesses the knowledge patterns of various identities within the classroom. The current movement to apply metaphor to understanding natural systems is becoming more common in supplemental texts and children's educational storybooks. The use of metaphor allows students view science creatively and better connect scientific concepts to their own everyday experiences.

Continuing with an analysis of teacher-student conversation within the classroom, this next study focuses on how student identity and concept comprehension is expressed during sixth grade student presentations of their science fair projects (Gomez, 2007). The study was conducted during the first three months of the 2000-2001 school year and focused on data that describes how the participating teacher framed the nature and processes of science for his students and how he responded to his student's presentations. This work is relevant to the research on developing a science identity as it presents an in-depth analysis of one teacher's process of inviting his students into a new and specific science domain. Sixth grade represents an age when students for the first time are coming into constant contact with a scientific perspective of understanding the world. This is a critically sensitive time in absorbing, internalizing, accepting or rejecting the scientific perspective being offered to them. Without proper bridging and recognition of students' individual identities, students unfamiliar with the mental and descriptive terrain of science curriculum could potentially have difficulty in connecting science to their current realities and self-identifications.

Though the audio data collected was representative of teacher instruction, science fair preparatory instruction, project development, and project presentations, the data in Gomez' paper only describes one 140 minute class period of science fair presentations. 90 percent of the 30 students were of Mexican or Central American descent and most had attended the school since kindergarten or first grade. Gomez applied discourse analysis to both student talk and teacher talk, identifying features of both that suggested specific levels of science discourse engagement and identity-revealing qualities. Similar to other studies that attempt to categorize students into science subjectivities, Gomez identified three main groups of science students based on their presentation and project performance. The first group of students is able to combine science language and everyday language to explain their project concept and the underlying relationships supporting this concept. The second group had some insights about their researched concept, but also maintain misconceptions that prevent them from understanding and explaining their concept correctly. The last group of students also had good, understandable insights, but lack a formal science language to correctly express the relationships that underlay their project concept.

During the presentations, the students followed a traditional presentation format that had been instructed by the teacher. Of particular interest in this study was how the teacher responded to students' expressions of their projects through the standard format. Often times, it was clear that students were using scripted language but did not necessarily understand this language. When this occurred the teacher would interject inquiries that would demand students to access everyday and science language to explain their reasoning. This teacher-student discourse added an additional challenge for students and revealed their true understanding of the scientific process as well as their project concept. Teacher responses were also often times opened to the class, creating another level of discourse which maintained student interest in the presentations. Upon the close of each presentation, the teacher had manipulated his critique in a way that rewarded students for their successes, but also presented improvement in the form of further research and deeper questioning. He gave options for how this was to be accomplished, and by focusing on what comes next he maintained the traditional characteristic of scientific thought as continuous, constructive, and infinite.

Gomez' discourse analysis is comprehensive and offers a solid insight into beneficial science fair discourse. While she addresses the duality of everyday language versus science language, Gomez emphasizes a hybrid interaction between the two language forms recognizing the importance for students to have an ability to access both simultaneously and complimentarily. Essentially, this is respectful to the nature of identity development; by encouraging new language through the allowed use of everyday language, students can bridge their previous identities to the perspective of a new science identity.

A major factor in determining appropriate and stimulating conditions in which students are compelled to try on new identity hats is the context of learning (Anderson, Zuiker, Taasoobshirazi, & Hickey, 2007). The subject of context was touched upon in the previous section on discourse in the critique of Reveles and Brown's (2008) work with contextual shifting. Anderson et al., (2007) addresses two primary facets of context, the dimensions of domain and participatory contexts. As all learning is uniquely situational, occurring within specific theoretical, behavioral, and linguistic domains (Gee, 2004, Lave & Wenger, 1991), participation in these situational domains is necessary practice for student learning. Thus Anderson et al. approach their study with a focus on assessments both formative and summative, as an essential discursive practice. Accordingly, participation is often stimulated through close-level questions and feedback, delivered by both peers and teachers. Also important to the authors was identifying proximal and distal-level examination and post-examination assessment strategies that correlated positively with the increased discursive participatory practices initiated in the close-level assessment stages.

Anderson et al., (2007) implemented a revised set of curricular activities developed from the Astronomy Village program in two astronomy classrooms of 11th and 12th graders. This implementation consisted of four 20-minute investigations, which were followed by close-level discursive activities and non-graded quizzes. Data presented was derived from the discourse analysis of four videotaped sessions of small group activities, with each group consisting of three or four students each. There were two implementation cycles, year one and year two, with different classroom teachers conducting the activities in each cycle. Based on teacher facilitation in year one, the authors refined methods of teacher facilitation that would be integrated into the curriculum for the year two implementation. The authors found significant qualitative differences between the two groups.

One major alteration to teacher facilitation that seemed to benefit student discourse and overall summative assessment scores was the style of teacher questioning that engaged students in the post-quiz, close-level discourse. Rather than asking rhetorical, definitive questions, the year two teacher asked open-ended, reflective questions. This adjustment seemed to trigger a creative and exploratory disposition more conducive to discussion, rather than a memory-retrieval, right answer disposition that limited discussion to one word responses and declarations of the unknown, such as 'we don't know the answer', and 'we won't know until they give us the answer paper.' The authors identified these responses as symbols of expressed defeat and learned helplessness, poor qualities of a discursive practice that is responsible for students participating in science talk and increasing a sense of science identity. By asking questions like "How'd you guys get that" instead of "What did you get", the year two teacher encouraged a discussion of reasoning that encouraged the students to talk science while allowing the teacher to gain understanding of how his students are processing and understanding the conceptual and linguistic aspects of this particular science domain.

Of further identity pertinence, the authors revealed how access to a specific science domain can be affected by the discursive practices not only by the teacher, but also by peer influence. In their analysis the authors identified situations where due to the minimal and helpless responses from some members of the group, other members did not have the opportunity to participate in the domain discourse. This is a perfect example of an ineffective performance of teacher scaffolding, directly correlated with discourse-stunting facilitation.

Anderson et al. (2007) provide a solid foundation of research describing the benefits of social learning and well-executed discourse. The length of their study and use of comparative groups created the opportunity to learn more about positive teacher facilitation practices and to also notice a correlating variance in student behavior and participation.

This research describes linguistic methods within science classrooms that foster science identity development. The ability to use specific science language enables the individual to connect with that domain and develop a corresponding identity. Pedagogical science teaching methods that encourage students to make science language connections with their non-science language through the use of metaphor appears to increase science concept development. The construction of science concepts and science language based upon previously attained foundational developments enables students to connect the new curriculum concepts with past experiences. Open ended and reflective questioning formats aid this process. The methods discussed in this section of research represent efforts to create a rich discourse within the science classroom which emphasizes language acquisition in supportive ways. As students are increasingly able to use language to understand how aspects of their realities can be interpreted with the application of scientific concepts, science will become increasingly meaningful. The next section continues with an emphasis on discourse in the form cooperative learning methods.

Cooperative Learning and Identity Development: Individual Versus Collective

Group discourse is an important factor for students in utilizing and developing there personal identities. When structured properly, cooperative learning activities employ strategies that allow students to express their identities and apply their behavior to a common goal within the group (Cohen, 1994). Cohen outlines several key ideas which teachers and curriculum designers can use to structure cooperative learning activities thus making group learning more effective; simply assigning students to groups and assigning tasks represents an unstructured approach to group learning and could arrest the development of understanding and social learning skills of the group (Giles, 2008). Giles conducted a quantitative experiment which involved six high schools in Australia to further elucidate the effects of structured and unstructured cooperative learning tasks.

Giles' (2008) experiment involved 164 ninth-grade student participants, with 77 students representing the structured condition and 87 students representing the unstructured conditions. Giles' controlled for certain variables including socioeconomic status, teacher's perception of science achievement, and interrater reliability. Five schools shared a similar socioeconomic status, with one school representing a slightly more impoverished population. The three schools that were chosen to implement structured cooperative learning group work maintained a strong commitment to cooperative learning and encouraged and trained teachers to develop structured cooperative activities and integrate them into their curriculums. Thus teachers in this group were familiar with implementing and facilitating group activities. Structured groups were composed of one high achieving student, two middle-level achievers, and one low-level achiever, to better increase the learning of all students and apply the beneficial practice of scaffolding and peer mentorship. Classrooms where unstructured group activities were practiced were not randomly stratified in student composition and unlike the structured groups, students did not regularly participate in cooperative learning activities.

All participating groups were given a group problem-solving task that required group participation in applying scientific classification procedures to a non-science related subject; in this case, they had to organize 42 different television programs into multiple categories and be prepared to present and explain their final product. This activity took place during the final two weeks of a four to six week unit; groups were videotaped only during the completion of the experimental activity, and by this time were familiar with being videotaped and the unit curriculum. Three essential measures were used to identify the effects of cooperative learning, these included behavioral observations, verbal interactions, and a science probe questionnaire. Behavioral observations focused on cooperative versus individual behaviors and were analyzed from observations collected in ten-second intervals for each student. These verbal interactions were delineated by directives, solicitation of help, interruption and specificity of verbal exchange. The science probe questionnaire, issued one to two weeks following the videotaped sessions, was derived from Bloom's taxonomy (1956), and required students to individually describe their learning during the classification activity, and apply their learning to complete a smaller classification activity. Scores between one (low, basic recall) and six (high, evaluative) were awarded by teachers who maintained a 100 percent agreeability rating.

Data was analyzed in multivariate testing (MANOVA) and Giles found many significant trends. Regarding the behavioral observations, students in the structured cooperative groups displayed higher cooperative behaviors and less non-cooperative and individual behaviors than the unstructured groups (significant at $p < .05$). Analysis of verbal interactions revealed that students in structured groups were more likely to give directive statements, and unsolicited and solicited explanations. Cognitive strategies were also determined through a MANOVA analysis, revealing that students in the structured group did not have to repeat information as often and issued more evaluative comments than students of the unstructured groups. On the science probe questionnaire, students of the structured groups scored on average one point higher than students of the unstructured groups. Despite limiting factors in this study which included small data collection (two weeks of videotaped learning sessions), unspecified and unobserved teacher practice of group work, and unspecified teacher valuations of cooperative group work, the researcher interpret these findings to be highly supportive of structured group work.

Connecting this research to the nature of identity introduces a new aspect on science identity. In this case, students' individual identities were encouraged to take a more collaborative, science-based approach in their interactive learning. In the structured group, students were successfully bridged to work as a collective unit, thus supporting an individual science identity. Also, the idea of a collective science identity is somewhat contradictory to students' established perceptions of practical science work. Encouraging students to conduct science work in a group reveals the social nature of practical science work, which acts as a bridge for students towards a science identity by allowing them to participate with peers using their previous and known-social identities. Further research seeking to determine the correlative nature between the development of science identity and cooperative learning activities could be structured to include a deeper analysis of specific discourse language, and the positive/negative nature of the subjective expressions of each student.

Multiple Literacies

Building inclusive, inquiry-based scientific discourse communities within the classroom is believed to be essential for student achievement in science education (NSF). To be inclusive means to create opportunities for all students to access, understand, and internalize scientific concepts and methodologies. Whereas more traditional techniques of teaching science demanded memorization and textual literacy, progressive ideas emphasize hands-on components and the implementation of activities that span a wide breadth of literacy formats, i.e. computer programs, visual art, conversational dialogue, experiential situations, and web-based technology. Expanding science curriculum materials to include non-text literacies attempts to connect students to science by accessing their individual learning preferences and capabilities. With our youth becoming increasingly dexterous in communicating through multiple modes of literacy, some of these being non-text literacies, adapting science curriculum to include more student-relevant formats of literacy could be more inviting to students who are in the process of developing a scientific identity.

The several captivations of the Internet entice many to engage with a computer screen for extended periods of time. The Internet provides much potential for various forms of communication via chat rooms, blogs, email, and wiki sites. Teachers are beginning to use the Internet in relevant and useful ways that include student participation opportunities. Jang (2009) conducted a four-month qualitative study in a Taiwanese school based on the implementation of an online homework and question-discussion formats. Jang's purpose was to identify how technology can be utilized and integrated with real-life science materials to stimulate student creativity and increase student motivation. The study involved 31 seventh grade participants and one teacher, dedicated to a love for learning and a willingness to progress. The researcher and teacher collaborated on this project to integrate technology into the classroom. Effectivity of the program implementation was assessed through student responses during interviews, videotaped recordings of in-class situations, students' online data, and teacher journals.

Jang's (2009) research revealed learning patterns that suggested students increased motivation in learning and comprehension of scientific concepts during the program. Students claimed that an online discussion format was much more interesting than reading a textbook reading and classroom discussion, and being limited in time to share ideas and answers to questions. In the classroom, students' performance in socially interactive projects improved, possible due to online preparations and peer-interactions. Jang's study benefited from prolonged and substantial engagement with the classroom, and an extended duration of the intervention which allowed ample time for students to grow comfortable with their online classroom community and to integrate traditional forms of learning.

There are some major limitations to consider within this study however. One, nothing is said of the socioeconomic status of the participating students and the school they attend. This program requires students to have access to internet and be literate with various online formats. Applying this program to schools and communities lacking these resources is unrealistic. In terms of Jang's (2009) findings and conclusions, his actual data and processes of data analysis are not spoken of in great depth. It is uncertain from where Jang draws his conclusions and makes great claims to the success of the online program. That said, there appear to be great benefits for students who engage in online discussions. In an online context, conversation occurs in a much different context than in physically intimate settings like a classroom, and students can participate with more focus on their personal experiences, free from the social pressures and social rules that are so prevalent in a middle level science setting.

Recent research involving the use of computer-aided learning in the classroom does not always promote science development (Waight & Abd-El-Khalick, 2007). Waight et al. (2007) performed a case study which focused on the impacts of technology on inquiry-based science activities and overall science discourse patterns within the classroom. There were 42 total participants, gathered in two sixth grade classrooms. Seventy six percent of the participants were African American, and 24 percent were White. The school was located in a mid-size Midwestern town. The teacher was a technology enthusiast, and introduced the computer programs to her classroom. Data was collected over a period of four months, during 66 science sessions. Research methodologies included videotaped classes, data entry in a logbook, and critical incident interviews. These interviews were conducted shortly following the activity, in which students were asked to respond to a review the lesson after first watching themselves on the videotape recording.

Researchers observed much enthusiasm from the teacher concerning the new integration of computer simulation programs into her curriculum. These simulations mimicked ecological systems, allowed for organismal dissections, and also performed as a science search engine. Despite the seemingly capable functions of these programs, researchers found that inquiry-based science did not improve, and possibly deteriorated. Data analysis showed that when this technology was implemented peer-peer and peer-teacher interactions and discourse decreased, as did teacher instruction. Despite the teacher's enthusiasm, she utilized the computer programs by giving students information retrieval assignments, which could easily have been completed with a textbook. Although the teacher was indeed using a different mode of literacy in her lessons, her lesson structure and task expectations did not change. Thus students were performing the same inquiry-related methods that were employed in a typical textbook activity. Though the intentions of inquiry were present, it seems that the teacher's understanding of inquiry does not match that of the National Science Foundation and the National Research Council. Indeed, student interviews revealed that only one out of ten students provided a reasonable definition of inquiry.

As reform of science education currently translates into a move towards inquiry-based curriculum design, it appears that some teachers have different ambitions in accomplishing this reform. The notion of technology equating advancement does little in reforming the mindset and understanding of these implementations. Student identities seem to be increasingly connected to computer-based technologies, and by utilizing this format of literacy, students can continue to explore their identities with this well-practiced tool. However, without reforming educational pedagogy to include individual and social developmental components, technology continues traditional trends of ritualized information processing rather than conceptual, personal learning.

The capabilities of virtual hands-on computer programs in use in science classrooms today are arguably comparable to real, tangible hands-on activities in terms of concept attainment and gains in the learner's knowledge (Klahr, Triona, & Williams, 2007). Considering identity development, hands-on activities often provide learners with a group context and the opportunity to manipulate materials in order to test a viable hypothesis, thus expand one's conceptual understanding via their own means. This emphasis on learning through doing, allows students to participate in the processes of practical science, potentially increasing their development of science identity. Klahr et al., set up a quantitative experiment that compared the effectiveness in learning between hands-on physical activities and virtual simulation of the same creative activity; in this case, the building of a mousetrap car. Both versions of the assignment allowed students to construct a car(s) either physically or virtually and then compared the knowledge attainment between groups. Within both the control and the experimental group, their were two subgroups, one being allowed multiple opportunities to create a car in a given time limit of 20 minutes, the other only granted six total opportunities for design. With both groups doing hands-on science, the researchers tested to see if one particular form of activity yielded more positive results.

Participants included 56 seventh and eighth graders (20 boys, 36 girls) from two private middle schools in a rural area of southwestern Pennsylvania. A pre- and post-test were used, that inquired about the influential features of the car that determined the distance the car would travel. The pre-test contained one additional question asking if the participant had created a mousetrap car before, while the post-test asked an open-ended question concerning any additional features that might influence the car's distance capability. After ANOVA tests were completed, all groups were nearly equal in post-test knowledge levels. Levels of confidence improved to the same extent, while girls' confidence increased more than boys' between the pre- and post-tests, however still was not higher than the boys after the post-test.

This research provides a new scope for viewing physical hands-on activities. If indeed the knowledge benefits are nearly identical for properly designed physical and virtual programs then why not enable students to become more familiar with computer skills and reduce the amount of physical materials a teacher needs to perform experiments? It seems both types of activities create opportunities for the learner to test their knowledge and create their own models, the physical model-making provides the student time to apply their bodies in kinesthetic ways, possibly improving hand-eye coordination and additional learning with the physical properties of materials. In this regard, Klahr et al. (2007) only test for knowledge acquisition, ignoring social and physical skills. There are many questions that remain to be answered about other benefits to either physical activities or virtual activities. With the perspective of identity development, engaging students in multiple types of activities enables students to explore science through a wider variety of literacies and knowledges. Virtual simulations allow students to make mistakes without the damage of materials or failing to construct a physical model. In this case, students became familiar with the properties of a mousetrap car without having to create a physical model. Nonetheless, Klahr et al., offer a curious proposition that challenges two very different types of hands-on activities.

While the previous studies inquired about the effects on learning of integrated web technology and advanced developed computer learning simulations, Sullivan (2008) critiqued six textbook sources used in advanced placement and honors courses for relevant non-text photographs. An increase in student appeal towards visual learning situations is evident of the increasing visual context-based modes of media and entertainment within our society. In consideration of urban school settings, Sullivan focused on the extent to which scientific texts connected conceptual understandings with urban contexts, via the depiction of urban landscapes in photography, captions and textual context.

Since 79 percent of Americans reside in an urban setting (Sullivan, 2008), it is important that students from urban centers have opportunities to apply their scientific knowledge to their urban communities. Sullivan used quantitative and qualitative measures to analyze popular science textbooks for urban cultural relevancy. He found of the 17 percent or greater amount of photographs depicting urban settings within the textbooks, they often appeared in urban ecology sections located at the back of the textbooks. Depending on how teachers chronicle their curriculum, if teachers follow the order of the textbooks, the urban ecology unit might be abbreviated or sacrificed entirely at the end of the year.

Sullivan (2008) then categorized the percentage urban photographs in each textbook into 14 codes. The content of photographs covered the unhealthy aspects of urban areas such as pollution, congestion, overcrowding, and impoverishment as well as the positive aspects such as sustainable practices and well cared for urban ecological environments like parks and greenbelts. The codes Sullivan developed are by and large inclusive of a great variety of ecological variables that should be covered during an urban ecology unit. In light of the great diversity in human ecology within urban settings, Sullivan could have developed a code that recognized this variable.

Another strength of this study regards Sullivan's inclusion of the supporting text in his analysis acknowledges that the textual context of the photograph plays an important role in its interpretation. From this evidence, many hypotheses could be formed predicting the levels of effect of these urban depictions, however Sullivan excludes the interactive processes of teachers and students engaging in these textbooks from his research.

One major drawback to this study concerns the targeted audience of these textbooks. Advanced placement courses are often composed of college-bound, high achieving middle to upper class students. The students are much more successful in science education than lower track students and have a higher chance of having developed a scientific identity than their lower track peers. While non-human ecological variables and human-inflicted ecological effects are considered, failing to address the diversity of human ecology ignores a critical component in developing a scientific identity: the socio-communal connection, which involves empathy, opportunities for positive social interaction, and community health. Though these are sociological constructs, they are necessary for students to understand their scientific identity within a greater discourse community.

This final body of research represents the challenge to integrate modern technology and multiple literacies into science curriculum. As has been stated that writing, reading, and talking science are necessary in the path towards developing a science identity, the modalities in which these processes are practiced are always evolving. For example, the potential of the Internet as a venue for students to practice science and play out virtual and projected identities extends the classroom from the school to the familiar playgrounds of the Internet discourse. Also, various virtual computer programs enable students to participate in hands-on activities, visually stimulating activities that increase conceptual understanding while triggering aspects of the students' non-science identities.

Summary

In consideration of this large collection of research, a science teaching pedagogy that encourages all students to participate in science, and engages them in a direction towards developing a science identity can be further developed. Attending to the goals of the national science foundation, It is no simple task to simply make science accessible to all students, especially considering the historical, socioeconomic, and gender-related barriers that have been presented in this paper. In this sense, the U.S. now encounters an educational situation unique from all other countries; one that must not continue to homogenize science into a traditionally Eurocentric, masculine, heteronormative pursuit, but must advance in a direction that presents the scientific process as what it is; a systematic process of understanding the entire realities of us and around us, inclusive of the individual qualities and differences that make science and life compelling.

CHAPTER FOUR: CONCLUSION

Introduction

The aim of this chapter is to integrate the research presented in chapter three into a pedagogical approach that emphasizes the malleable nature of identity, and how to best help student develop a science identity. As stated already, developing a science identity must first be understood to be only one identity of multiple identities, or subjectivities, a young student manages and shifts between in their daily lives. Identity must then be conceived on multiple levels, and not be solely defined as one's only operating orientation that dictates their entire comprehension of the world around them. Thus, the goal of science education is not necessarily to produce scientists, but allow students to develop a science perspective to which they can critically understand scientific pursuits within our local, national, and global communities and advance science in creative directions that will raise awareness of universal systems and sustainable habitation.

The following sections will review the primary themes, critiques, and conclusions as presented in chapter three. Implications of this research as well as suggestions for future research will also be presented.

Summary of Findings

Another World: Student's Congruency with Science Education

Strategies for understanding students' backgrounds are included in this paper because bridging students towards developing a science identity cannot occur without awareness of student's pre-existing identities. Strategies to determine students' backgrounds are indeed bridging strategies of themselves and when these processes are conducted in classroom discourse, there is the potential for students to invest themselves in the identity of which the instructor practices and teaches. This principle of authentic caring applies here and functions as an invitation to students to classroom learning.

Applying authentic caring to valuation of individual identity within the classroom translates into presenting science as a tool that students may find useful and applicable to their lives. As Kozoll & Osborne (2004) described in their case studies of the interviewees' lifeworlds, when a student is able to directly apply science to their lives and ambitions, they are more likely to adopt a science identity. Regarding the responsibilities of a teacher, this requires acute perception of student's lifeworlds, a familiarity with a multitude of science practices, and an ability to create curriculum that will be of use to the students.

Depending on students' specific lifeworlds, many students will vary in whether or not they are supported outside of the classroom to take on a science identity. Costa (1995) identifies a spectrum of student congruency between their outside worlds and a science world inside the classroom. This is another type of awareness that science teachers must work to achieve. Students who are unsupported in their everyday lives and do not have any reason to value a science perspective, offer a significant challenge in the classroom. Being sensitive to the lack of support a student faces outside of school could enable trusting bonds to form, and evolve into open discourse within the science classroom, thus allowing the potential of science discourse to begin to form.

This discourse can also be encouraged through storytelling and the creation of a safe, specific space in which students can share personal stories and experiences. This is a separate life skill in itself that is challenging to integrate into specialized classrooms. However, in doing so, as a teacher I will have a greater potential of connecting science curriculum to students' experiences and prior knowledge (Upadhyay, 2006). Also by allowing discourse to take place within the classroom, students will become familiar with each other's experiences, increasing the potential for more capable peer interactions to occur.

Empowering Marginalized Identities

One of the greatest predictors of success for students in science is locus of control (Chang et al., 2007). Similar to establishing a safe place for student expression, allowing the expression of prior knowledge and life experience to construct meaningful curricular activities will help students increase their sense of control over their ability to learn. Giving students project and curriculum options and multiple opportunities to prove mastery is one way teachers can empower students. Since locus of control is a relative construct, teachers need not give up entire control of their classroom as it might seem, but rather work with students' inputs and curricular standards to construct a well-suited curriculum (Dewey, 1938).

Buxton's (2005) study is a perfect example of what happens when students' locus of control is reduced and their prior-knowledge ignored. In the case of the Center for Science and Math (CSM), the teaching staff made up of science and math professionals often failed to account for the funds of knowledge students with which students were arriving to this specialized secondary school. This ignorance inhibited the development of bridges that could have connected the inner-city youth, who were coming from situations of poverty and incongruent lifeworlds with science identities, with scientific perspective. At CSM the professional teaching staff maintained high standards that were congruent with the rigors and expectations of college-level courses. This preparatory curriculum could have benefited first from drawing lower-classmen into the world of science through explorative activities that emphasized language and process development, rather than assume these skills should already be possessed.

Of the most significant populations to consistently fail in science education are the Native American populations (James, 2006). In terms of identity features, Native Americans who identify with Native American values hold identities that are incongruent with the values underlying the currently practiced western science models of today. In this perspective, it is not a case of accessibility, but of outright cultural incompatibility. While western science is a product conceived of western cultures, who value control over nature, mechanization, and a spiritually detached viewpoint, this is a science that is biased and in dire need of reconstruction. Ancient awareness held by native cultures around the world is rich with attributes of science, such as methodology and repeated, tested information, accomplishing the purest objectives of science that is to understand the world around us. Thus, knowledge brought in via the minds of various cultural influences should not be discounted on the principles that it is missing the methodological qualities of Western science. To do so not only continues the hegemonic discourse of Western science across a global society, but it also ignores potentially beneficial bodies of knowledge and awareness that could increase the integrity and power of science. Science teachers should consider integrating different forms of traditional knowledge, whether brought forth by their students or sought out be teachers themselves.

Traditional Ecological Knowledge (TEK) represents not only particular ways native cultures around the world view the environment and relationships within all ecological systems, it also represents the core of native identity (Sutherland, 2005). In an effort to bridge students to other learning identities, namely science, the new domain must offer the participant a means of access and the capacity to maintain their previous identities if they so desire (Gee, 2004). This reiterates the importance of allowing students to bring in funds of knowledge that might be intertwined around traditional knowledge and tradition. In the classroom, components that encourage the research and value of personal student heritage could be applied to science history and also current scientific pursuits.

De-emphasizing Gendered Science Prototypes

Although the masculine nature of science has definitely been reduced in recent years, the foundations of Western science still hold a significant influence on the professional field, and the trickle down effects into school administrations and classrooms. While life sciences seem to be becoming more gender-balanced, the physical sciences maintain a masculinity that is largely impenetrable by non-masculine genders (Hughes, 2001). To overcome such stereotypes and preconceptions in the classroom, it is important to present science in unbiased ways according to gender. This could include referring to work done by minority-genders within their specific fields, emphasizing the potential for any student regardless of gender to succeed in the corresponding field.

Another challenge science teachers face is the retracted or unmotivated efforts put forth by students who come to view science as a subject that will damage their social communities if they succeed or even participate in science class (Kessels, 2005). This is not an issue that is easily overcome. One effort to reduce this tension could be to establish a classroom community that respects science as an effort to understand life and the forces of universe, emphasizing the innately human compulsion behind the scientific endeavor. Another effort could be made to de-masculanize the physical science curriculum, and include problems, projects, and group assignments that are inclusive of feminine pursuits. Because of the masculine nature of Western science, gender equality remains an issue within not only the professional fields, but also the classroom. Students need to be made aware of the social trends and nature of Western science, so they can also participate in its reconstruction.

Discourse Community

After poring through the great amount of theoretical and experimental research being conducted in the past two decades on the subject of science discourse, I believe it is important to create a classroom community that fosters frequent exchange of science and everyday language, offers experiential activities with strong participatory discourse components. Part of this process involves recognizing science as a second language and as is typical for learning a second language, satisfactory acquisition occurs through a combination of reading, writing, and conversational activities. Roth's (2008) study reveals a style of 'talking science' that allows for students to form a hybrid language, combining science language with their everyday language. Not only does this process transition the students into speaking a science language, but it also functions as a bridge that connects students to a science domain. With this connection, comes a familiarity with science practices and behaviors, thus increasing the potential for science identity development. Hybrid language is especially important for students who speak a first language other than English or for students who have experienced recent immigration. In working with such students, creating situations where cultural identities can be accessed will help language acquisition and science identity development (Igoa, 1995).

The completely subjective nature of identity and identity perception warrants a teaching pedagogy that accounts for students' preconceived notions of what science is (Brown, 2005). Depending on how students view the practice of science and duties and characteristics that detail science endeavors, curriculum and discourse must reflect these student sentiments. However, one of my teaching goals will be to work with students to conceive science identities in positive and everyday ways. Just as scientists work with high tech instruments in laboratory environments, science also takes place in local community and natural settings. Engaging students in a variety of activities and experiences that diversify and diminish the science mystique will hopefully help students construct conceptions of science in which participation and understanding can happen during their everyday realities.

For students to understand the everyday nature of science and be able to apply it to their lives, science should be presented in causal discourse that reveals the interconnected nature of scientific concepts (Woodward, 1994). Causal understanding is especially important when considering civic participation in science-related local issues. To integrate this understanding into curriculum design, science teachers must bring local issues into the classroom to enable students to not only participate in science discourse within the classroom, but also in science discourse within their greater community. Helping students link their realities that include community relationships will create incentives for students to assume a science identity (Lee & Roth, 2003).

Implications for Teaching

This research has many implications for teaching. The utmost interest is the ability to redefine the culture, goals, and values of science. This must happen in a way that is cognizant of non-Western cultural values, community and ecological preservation, and traditional knowledge. To design a corresponding science curriculum must hinge upon a few primary considerations. First, teachers must recognize the cultures their students are from, and what cultural values those students embody. Though there is bound to be conflict between science curriculum and the cultural backgrounds of the students, this need not be a barrier for students to develop a science identity. Rather the ideas and values of students can compliment scientific concepts by offering a perspective of thought that differs from scientific thought patterns. For example, the traditional knowledge of Native populations comes from a rich, historical catalogue of experiences with the natural world. Though these experiences might not have been interpreted under the regiments of western science, they still represent the application of specific scientific modalities, such as observation and variable testing and isolating skills. Including this knowledge into curriculum, possibly as it arises, not only creates a student-generated discussion, but also can be critiqued to certain degrees as a scientific modality.

Second, teachers must attempt to understand why a student possesses aversions or disinterest towards science. During this process, many trends that were discussed in Chapter three could be applied to help understand student disengagement with science. For this set of practices, teachers must allow students to express their non-science identities within the science classroom. This has potential to create an environment that integrates science with the diverse lives of the students while allowing students to form collective identities that include science aspects. In addition, allowing for student expression and curricular inputs reveals pre-existing identities to the educator.

Last, teachers must accommodate various forms of language and literacy into the curricular development of scientific language. This includes allowing students to practice science language in a supportive discourse environment. Learning the language of science based on experiences and activities is necessary for students to develop a science identity. Science educators must work to create language-learning environments that are based on hands-on experiences and incorporate appropriate reflective writing and dialogue activities. All of these efforts are part of an implicative coalition that seeks to redefine science as an accessible and applicable pursuit to the daily lives of all students.

Further Research

As stated before, the present research base for science identity development is recent and limited. There is a small and focused movement to use the psychological aspects of identity to guide science curriculum design and classroom management, however, this is largely expressed through the intervention of hands-on experiential programs and activities. In order for this to be done effectively a better idea of what science is not doing to engage students and communities should be established. Of the research presented here, great efforts have been made to identify how and why students struggle to find consonance with scientific learning (Brown, 2005; Costa, 1995; Kozoll, 2004). These kinds of studies work to identify common barriers many students encounter during the developmental stages of science identity. Similar studies should be conducted in environments where large student populations are disengaged from science.

The main area of further research however involves the specific nature of how curriculum can still meet standards and also include the capacity for students to participate in the constructive contents of curriculum design. In other words, what is now needed is greater emphasis on designing curriculum that is functionally appealing and psychologically stimulating for students that do not fit the typical science-culture molds. This could include further ethnographic and subjective research that highlight educator interventions and make detailed notes of the composition of the interventions and how the students reacted. This could also include more synopsis of what successful student-driven science curriculum looks like in the classroom.

Finally, including the greater community into the shaping of science curriculum could lead to deeper communal interest in science, and thus have a positive effect on students as they develop science identities. This reference to bioecological theory (Bronfenbrenner, 2005) assumes that as the collective identity of the community integrates scientific understanding to the problems and thought patterns of the community, then students of that community will be far greater supported in the development of their individual science identities.

Conclusion

In conclusion, this paper has addressed the nature of science identity and the variables that impede or encourage students to develop a science identity. These barriers and bridges towards a science identity were defined in chapter one, realized in chapter two, and researched in chapter three. The ability of a student to develop a science identity correlates strongly with their capacity to engage and succeed in scientific learning. Science educators should therefore place heavy emphasis on helping students identify with science concepts and accommodate these concepts into an aspect of their greater identity that is scientifically oriented. In a science classroom, students should be able to develop as science learners, as people who can understand the world in a scientific way. This is not necessarily the only way to interpret the world, but represents a dominant perspective within the world with learning that can be applied to solve some of the world's greatest calamities. If students are seen as malleable entities upon entering the classroom, whose learning is dependent on making connections between present curriculum and past experiences, then actions can be taken to ensure that students are able to explore these connections in a safe and identity-supporting environment. In developing awareness for how students struggle to identify with science, science educators can better collaborate with students to construct bridges that successfully connect students with a science identity.

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