Published in final edited form as:
*Res High Educ*. 2009 March ; 50(2): 189–214. doi:10.1007/s11162-008-9114-7.

# Diversifying Science: Underrepresented Student Experiences in Structured Research Programs

**Sylvia Hurtado**, **Nolan L. Cabrera**, **Monica H. Lin**, **Lucy Arellano**, and **Lorelle L. Espinosa**
University of California, 405 Hilgard Ave., 3005 Moore Hall, Los Angeles, CA 90095-1521, USA

Sylvia Hurtado: shurtado@gseis.ucla.edu

## Abstract

Targeting four institutions with structured science research programs for undergraduates, this study focuses on how underrepresented students experience science. Several key themes emerged from focus group discussions: learning to become research scientists, experiences with the culture of science, and views on racial and social stigma. Participants spoke of essential factors for becoming a scientist, but their experiences also raised complex issues about the role of race and social stigma in scientific training. Students experienced the collaborative and empowering culture of science, exhibited strong science identities and high self-efficacy, while developing directed career goals as a result of "doing science" in these programs.

### Keywords

Undergraduate science research; Racial/ethnic minorities; Stigma; Identity; Self-efficacy

## Introduction

Increasing the number of students completing advanced scientific degrees that lead to scientific research careers is critical to national interests. A declining cadre of skilled workers for scientific fields portends a decline in U.S. global competitiveness and the exportation of high-skilled jobs to other countries (Augustine 2005; Council of Graduate Schools 2007). Contributing to this decline is the trend that roughly half of those students who display initial interest in majoring in science disciplines change their plans within the first two years of undergraduate study, and very few non-science aspirants become science majors (Center for Institutional Data Exchange Analysis 2000). National efforts are now focused on purposefully reversing these trends. Indeed, *Rising Above the Gathering Storm*, a report released in 2005 by the National Academies of Science, was a strong call to action that resulted in passage of the 2007 America Competes Act to strengthen science-related education, programs, and research (see Augustine 2005). However, more research is needed on the growing numbers of college students from underrepresented communities. Understanding more about how talented racial/ethnic minorities experience "becoming scientists" in undergraduate science programs provides insight into the complexities of diversifying the scientific workforce.

By the year 2015, there will be a substantial increase in the number of racial/ethnic minorities entering college (Carnavale and Fry 1999). If the nation's colleges and universities are to graduate the next generation of research scientists, they must be aware of



Correspondence to: Sylvia Hurtado, shurtado@gseis.ucla.edu.

the number of racial/ethnic minorities in the science pipeline and make efforts to successfully recruit and retain students, as this group has great potential to influence change in the scientific workforce. Unfortunately, the rates of science baccalaureate completion for underrepresented minority (URM) undergraduates are dismal: only 24% of African American, Latina/o, and Native American students complete a science bachelor's degree in six years, compared to 40% of White students (Center for Institutional Data Exchange Analysis 2000). This underrepresentation has an additional negative impact on communities of color as URM scientists are more likely than non-URMs to study issues specific to minority communities (Nichols 1997). Among the three dominant disciplines that comprise the biomedical and behavioral science (BBS) fields—biological sciences, chemistry, and psychology—URM students represented 18% of bachelor's and 7% of doctoral degrees in 2004 (National Science Foundation (NSF) 2007). These statistics are especially concerning given the necessary function of graduate education for those entering scientific research careers.

Partly in response to the alarming underrepresentation in the sciences, colleges and universities have employed undergraduate research opportunities to keep students engaged in scientific discovery. Indeed, scholars consistently identify undergraduate research experiences as one way to attract and retain science majors, enhance the educational goals of science undergraduates, and serve as a pathway toward scientific careers (Kinkead 2003; Lopatto 2004). Numerous programs—many of which explicitly target URM students—aim to initiate undergraduates into research careers through mentoring experiences and hands-on research training, while allowing student understanding of what a scientific career would entail (Kinkead 2003). Further, many of these programs provide an avenue for student-faculty interaction, which often leads to increased academic achievement, educational aspirations, self-concept, and persistence (Astin 1993; Cole 2007; Pascarella 1985). Several of these outcomes were more pronounced for Latina/os and African Americans when their interactions involved research and mentorship with faculty (Anaya and Cole 2001; Cole 2007; Cole and Espinoza 2008).

In addition to university-level efforts to improve the number of URMs aspiring to pursue BBS degrees, a steady stream of federal funding aims to support student persistence in these fields. Programming sponsored by the National Institutes of Health (NIH) over the last 30 years aims to prepare students for BBS research careers in college (NIH 2007). These efforts have specifically attempted to provide students with the tools needed to acquire both academic and practical knowledge leading to scientific research careers through summer bridge experiences, academic assistance, and research opportunities, while further providing underrepresented students (as well as their universities) with financial assistance. This study aims to contribute to the ongoing inquiry into the efficacy of intervention efforts through undergraduate research programs. Given the importance of undergraduate research exposure in training URM scientists, we examine the benefits and challenges students experience in undergraduate research programs intended to diversify the scientific workforce. We specifically seek to identify postsecondary contexts that promote diversity and engagement in the sciences with the goal of not only retaining students but also furthering their preparation for post-baccalaureate pathways that lead to advanced studies and scientific research career goals.

## Diversity and Science

Common assumptions regarding racial and ethnic inequality focus on a perceived lack of motivation and preparation within minority populations (Schuman et al. 1997). Contrary to this belief, studies have shown many academically well-prepared high school URM students are interested in pursuing scientific and engineering careers (see for example, College Board

2005; Hurtado et al. 2006; NSF 2004). In 2005, the same percentage of African American and White (44%) college-bound high school students indicated their intent to major in science and engineering fields (College Board 2005). Further down the educational pipeline, only 27% of URMs and 46% of majority students who intended to major in a science or engineering field obtain a scientific degree (Huang et al. 2000; NSF 2004).

In contrast, minority-serving institutions (MSIs) have consistently produced the highest number of science baccalaureates for African Americans and Latina/os (Li 2007; Provasnik and Shafer 2004; U.S. Department of Education, National Center for Education Statistics 2002), and the NIH has typically funded undergraduate research programs in science at these institutions. What is distinct about student experiences in these contexts? First, Allen (1992) found that African American students were more satisfied with faculty-student contact at Historically Black Colleges and Universities (HBCUs), but were more satisfied with the resources at predominantly White institutions (PWIs). In addition, Black students at HBCUs tend to be more satisfied with their sense of community and student-to-student interactions relative to Black students at PWIs (Outcalt and Skewes-Cox 2002). MSIs have also promoted more inclusive campus climates, which increases the cultural continuity between minority students and the institution (Abraham et al. 2002; Zamani 2003).

Specific to students in the sciences, high institutional selectivity is typically associated with decreased retention in the field for all students, but it is associated with increased URM retention in these fields at HBCUs (Chang et al. 2008). As Chang et al. (2008), argue:

> [M]ore selective HBCUs appear to approach the process differently and seem to focus less on further "weeding out" students. Once a rich talent pool has been identified, they seem to do a better job of socializing and cultivating that talent to improve students' chances of succeeding in the sciences. (p. 455)

Thus, it is not surprising that of the top 15 institutions for graduating Black BBS majors in 2004–2005, only two were not HBCUs (Biological and Biomedical 2006).

The impact of Hispanic-Serving Institutions (HSIs) on Latina/o student science outcomes is substantial, but not as dramatic as HBCUs in promoting Black student success. Of the top 25 institutions for generating Latina/o science baccalaureates, eight are HSIs (NSF 2004). Interestingly, four-year HSIs actually produce a disproportionately low share of science, technology, engineering, and math (STEM) bachelor's degrees relative to their Latina/o student enrollment (Contreras et al. 2008; Malcolm 2008). This could be, in part, a function of the programmatic offerings at less selective HSIs (Malcolm 2008). In addition, HSIs tend to function like PWIs in BBS student retention: as selectivity increases, URM BBS retention decreases (Chang et al. 2008). However, HSIs frequently produce high levels of student engagement and sense of belonging that can lead to increased academic retention (Abraham et al. 2002). Additionally, institutions must have a minimum of 25% Latina/o enrollment to be designated "Hispanic-serving," but students may still be racial/ethnic minorities in those environments (Laden 2004). Overall, there is relatively little literature on the role HSIs play in promoting Latina/o educational outcomes relative to HBCUs.

Empirical research has consistently pointed to undergraduate research experiences as a powerful tool to attract and retain students in science majors, promote graduate school aspirations, and serve as a pathway toward careers in science (Kinkead 2003; Lopatto 2004). Several studies have identified a broad range of benefits stemming from undergraduate research including: improved knowledge and understanding of science (Sabatini 1997); development of technical, problem-solving, and presentation skills (Kardash 2000; Mabrouk and Peters 2000; Seymour et al. 2004); clarification of graduate school or career plans (Kardash 2000; Sabatini 1997); and the development of professional self-confidence

(Lopatto 2003; Mabrouk and Peters 2000). Fundamentally, these programs exist to enhance student interest in becoming a scientist and we seek to examine URM student experiences in these programs.

## Developing a Science Identity and Scientific Self-Efficacy

Carlone and Johnson (2007) developed a grounded model of science identity using research on successful women of color in science. Based on qualitative studies, they conceived of the prototypical individual with a strong science identity to be someone who demonstrates *competence* in the discipline through one's knowledge and understanding of science content. Such an individual also possesses the necessary skills for the *performance* of relevant scientific practices (e.g., application of scientific tools, facility in engaging in scientific talk). Finally, this individual achieves *recognition*, by acknowledging oneself and being recognized by meaningful others as a "science person." Thus, the model addresses three overlapping components of science identity: competence, performance, and recognition (Carlone and Johnson 2007).

Furthermore, Carlone and Johnson's science identity model is formulated on the explicit assumption that an individual's gender, racial, and ethnic identities influence one's science identity. They purposefully highlight the interrelated dimensions of identity formation to make clear the importance of taking into account the social construction of science identity. As Carlone and Johnson point out, "[O]ne cannot pull off being a particular kind of person (enacting a particular identity) unless one makes visible to (*performs for*) others one's *competence* in relevant practices, and, in response, others *recognize* one's performance as credible" (2007, p. 1190).

Carlone and Johnson highlight a similar argument from Lewis (2003) in his critique of the research literature on the underrepresentation of African Americans in the sciences. Specifically, Lewis believes much of this research has overlooked how "science career attainment is a social process, and the desire of an aspirant is only one factor in this process. An aspiring scientist relies on the judgment and invitation of practicing scientists throughout every phase of the educational and career process" (2003, p. 371). Following these lines of reasoning, fostering science identity development involves more than focusing on individual factors such as increasing one's level of competence in science. It also involves social factors, including socialization into the sciences and making meaning of science-related experiences, such that an individual not only *feels* like a science person, but also *acts* and *is seen by relevant others* as a science person.

Related to the development of science identity is the development of scientific self-efficacy. According to Bandura (1997), self-efficacy is developed through a dynamic interplay of individual perceptions and behaviors and the external environment. He defines the perception of self-efficacy as "judgments of personal capabilities" (p. 11) and argues that "people will explore, and try to manage situations within their perceived capabilities, but unless they are externally coerced, they avoid transactions with those aspects of their environment that they perceive exceeds their coping abilities" (p. 14). While external expectations can promote the development of self-efficacy, they can also inhibit it.

Bandura (1997) explains that when a devalued group becomes the target of blame for negative characteristics that others associate with them, group members may eventually believe those degrading qualities about themselves. The influences of environmental structures are significant, but they are only one part of the equation, as Bandura also rejects a socially deterministic view of self-efficacy. He instead gives equal attention to the possibility that people within socially disadvantaged circumstances can overcome said obstacles if their perceptions of individual efficacy and behaviors are able to compensate for negative external ascriptions (Bandura 1997).

Thus, the development of a science identity and self-efficacy emerge as strong and pertinent theories that give credence to the influence of social structures without being deterministic, while simultaneously espousing the importance of individual beliefs and behaviors without eroding into Horatio Alger myths of "pulling oneself up by the bootstraps." The interplay between students and structured, undergraduate research programs frequently develops student science identity and self-efficacy through five main components: mentoring, financial support, academic support, psychosocial support, and professional opportunities (Gándara and Maxwell-Jolly 1999). For example, the Biology Fellows Program (BFP) at the University of Washington aims to enhance diversity in science by helping students succeed in rigorous introductory biology classes and motivating them to engage in research early in their undergraduate careers. Program assessment (which controlled for selection bias) found that BFP participants saw themselves as competitive scholars capable of pursuing research opportunities even if they had not yet taken the university's introductory biology course (Dirks and Cunningham 2006).

Another academic enrichment program for biology majors, the Biology Undergraduate Scholars Program (BUSP) at the University of California, Davis, offers academic and career advising, supplemental instruction, academic enrichment in biology, chemistry, and mathematics, as well as research exposure and mentoring. Program participants, who are largely from minority backgrounds, credit research participation as a driving force in pursuing research careers, even if students were initially interested in becoming a medical doctor (Barlow and Villarejo 2004). These initiatives are very important because there continues to be a number of issues in the "way science is done" that systemically marginalize URM participation, and this consistent underrepresentation calls into question the contemporary culture of science.

## The Contemporary Culture of Science

Although URMs are entering college interested in science at increasing rates and these populations benefit from scientific inquiry on several levels, their inclusion tends to represent token participation rather than meaningful incorporation (Harding 1993; Nicholas 1997). The emergent "culture of science" may inhibit the development of URM research scientists, especially when it affects their notions of competence that are central to their developing identity of "becoming a scientist" (i.e., the potentially adverse impact of negative external messages on URM academic success). It is important to study how underrepresented students successfully navigate exclusion and their unique representation in science on their path toward becoming a scientist.

While research experience and exposure is paramount to the encouragement of undergraduates' entry into scientific careers, students must also navigate an academic culture—both in college in general and in science majors in particular—that is fraught with academic and social obstacles. There are numerous psychological and sociological factors that both promote and inhibit whether a student becomes a scientist (Hurtado et al. 2007; Seymour and Hewitt 1997). Among these factors are the overall racial climate of the university and the BBS academic culture. Also, students frequently encounter competitive science environments coupled with stereotyping and social stigma, resulting in a lack of supportive peer networks (Fries-Britt 1998; Treisman 1985). A competitive and hierarchical atmosphere is just one of many known aspects of the scientific culture that presents itself to students in different ways. While many recognize a distinct and pervasive "culture of science" at colleges and universities around the country, creating a definition of this culture is challenging.

Bronowski (1972) suggested that “the scientist does not merely record the facts; but he [or she] must conform to the facts” (p. 28). This means following the rules of the scientific method while at the same time upholding subsequent standards of the scientific community (Bronowski 1972). Scholars of science education recognize that it is not only the *way* in which science is produced, but it is also *how* the culture is perpetuated. Hutchison and Bailey (2006) describe the latter point: “the sheer inertia of the cultural conventions becomes the agency by which that culture reproduces itself; hence the need for conformity is a reproductive process” (p. 663). All three scholars—Bronowski, Hutchison, and Bailey—speak to the larger body of knowledge encompassing the way science has evolved. Specifically, the culture of science has two primary tenets. The first speaks to the collective “culture” that dictates those practices deemed acceptable within the discipline of science. The second is individualistic in that it refers to how an individual practices science. This latter tenet emphasizes the way in which students are “being initiated into scientific ways of knowing” (Driver et al. 1994, p. 6). Students thus gain exposure to scientific culture and are actively taught or shown the way in which “science is done,” having to navigate both areas within their university-specific setting, which may or may not serve individual learning needs.

The scientific culture is further attributed to the environment in which students find themselves. For example, those intending to major in science often confront their first significant obstacle in the form of introductory science classes, also known as “gatekeeper” courses due to their role in limiting access to science degrees by “weeding out” those students whose academic competencies are allegedly not sufficient for success in the discipline (Seymour and Hewitt 1997). Gatekeeper courses often result in high attrition rates for all students but disproportionately affect URM students, particularly those who begin the freshman year with a competitive disadvantage due to substandard high school preparation (Schneider 2000; Vetter 1994). Pedagogical practices present in many science classes, such as grading on a curve, promote intense competition among students while discouraging cooperation and fostering a “survival of the fittest” mentality (Epstein 2006). Even the most talented students may begin to seek other majors if their exposure to science is limited to large courses that do not engage their interests or lack a sense of real-world purpose to the study of science.

In addition to the culture of science, URMs frequently experience social stigma that can, in turn, inhibit their academic development. Specifically, when underrepresented students find themselves in classrooms, labs, or environments where they are one of a few, stigmatization can potentially affect students’ levels of academic self-confidence and performance. Contemporary outlooks on stigma emphasize the degree to which targets’ understanding of how others perceive them, their construal of social contexts, and their motives or goals, can in fact mediate the effects of stigma (Major and O’Brien 2005). For example, Steele and his colleagues (Steele 1997; Steele and Aronson 1995) found that negative social stereotypes give rise to stereotype threat, a situation-specific fear that one will either be evaluated on the basis of stereotypes or perform in such a manner to confirm those stereotypes. When stigmatized individuals find themselves in stereotype-relevant situations, their self-awareness of stereotypes heightens performance pressures in what may already be an anxiety-provoking experience, especially when the performance is challenging (Steele 1997). However, situations that diminish the relevance or salience of performance stereotypes should reduce stigmatized individuals’ concerns that inadequate performance will serve as confirmation of the stereotypes, thereby facilitating performance improvement (Steele 1997). The role of programs that target underrepresented groups for engagement in science research and academic activities has been understudied. We do not know whether such programs reduce stigma related to race and performance stereotypes, or whether students face these issues regardless of program participation.

Given that individuals with stigmatized identities manage to flourish in academic settings and other environments, we seek to place attention on the processes that individuals successfully use to overcome the detrimental effects of stigmatization (Oyserman and Swim 2001). These processes may include compensation for stigma through development of key skills, strategic interpretations of the social environment, and incorporation of multiple identities into one's self-concept to deal with prejudice and discrimination (Shih 2004). Thus, any structured, institutional strategies or interventions that address the effects of stigmatization in postsecondary learning environments will be faced with differing values and meanings of racial and ethnic group identities for undergraduates.

The American Association of Colleges and Universities (AAC&U) introduced the concept of *inclusive excellence* to start a campus movement to reframe notions about who has access to a liberal education, and how to prepare all students in the 21st century (AAC&U 2007). With respect to URM participation in science, it can be said that the programmatic initiatives targeting underrepresented populations attempt to create a new paradigm of *inclusive excellence* regarding who will become a scientist. Applied to teaching and learning in science, we think the student voice is critical in understanding how they experience science training with the aid of programs that attempt to equalize both educational opportunity and resources that are distributed across institutions.

## Methodology

This study employed a phenomenological approach (Creswell 2003; Yin 1994) to examining and understanding how URMs develop scientific research career goals. Part of this approach meant analyzing the student perspective within structured programmatic experiences that promote a sense of science identity and scientific self-efficacy. As such, we conducted site visits and held student-level focus groups at the following institutions: Massachusetts Institute of Technology (MIT); University of Texas, San Antonio (UTSA); University of New Mexico (UNM); and Xavier University of Louisiana. These sites were selected because they produce high numbers of URM science graduates and offer formal science enrichment programs that support students in their majors and/or provide undergraduate research opportunities. We were further interested in having at least one institution—MIT—that did not rely on external sources of funding for undergraduate research. The other campuses utilize NIH funds to equalize resources by providing research opportunities for underrepresented students.

All but one of the targeted research programs are sponsored by the NIH. We purposefully recruited participants at UTSA and Xavier from two major NIH Minority Opportunity in Research (MORE) Programs: Minority Access to Research Careers (MARC) and Minority Biomedical Research Support (MBRS), including MBRS-SCORE (Support of Continuous Research Excellence) and MBRS-RISE (Research Initiative for Scientific Enhancement). At UNM, the NIH program used for recruitment was the Initiative to Maximize Student Diversity (IMSD). Students at MIT were targeted for recruitment due to their participation in what is known as the Undergraduate Research Opportunities Program (UROP), which is open to all students regardless of their background. It is the case, however, that URM students participate in UROP at slightly lower rates than their majority counterparts.

Three of the four campuses are MSIs (UNM, UTSA, and Xavier). At all four sites, we conducted interviews with programmatic administrators and conducted focus groups with students participating in undergraduate research programs. Each site visit lasted between one to two days. At the end of each visit, we compiled notes from focus groups, interviews, campus documents, and observations in a single notebook along with supplemental institutional documents. These documents provide the basis for triangulation across multiple sources of data (Creswell 2003).

## Data Source and Sample

We purposefully recruited student focus group participants through their campus' science programs and offered students refreshments and a gift card for their participation. While purposeful sampling may not have the generalizability of a random sample, we utilized it in our study to emphasize "information-rich cases that elicit an in-depth understanding of a particular phenomenon" (Jones et al. 2006, p. 65). Although we collected data from program administrators, site visit observations, and institutional documents, this study emphasizes the student voice through the analysis of student focus groups.

We developed a semi-structured focus group protocol that broadly addressed the following thematic categories:

- Developing an interest in science and subsequent educational and career goals
- Understanding the role and requirements of a scientific research career
- The undergraduate research program experience
- Ongoing challenges and obstacles facing URM students

Focus group sessions lasted between 45 and 90 minutes and ranged from 4 to 12 participants. Two research team members were present at all sessions, with one facilitating the discussion and the other taking notes. A total of eight focus groups (two per site) were conducted and each session was audio recorded and transcribed verbatim. The 65 student participants represented a racially diverse group: 60% Latina/o, 22% African American/Black, 5% Asian American, 8% multiracial, 3% American Indian, and 3% White. Women constituted 62% of the sample, and the majority of students (72%) were biology, biochemistry, or chemistry majors.

## Analysis

Upon the completion of data collection, multiple members of the research team reviewed focus groups transcripts to establish emergent themes relating to student development of scientific interest and career aspirations, support received in pursuing this goal, and present or continuing obstacles and challenges faced by students. According to Jones et al. (2006), "a theme is most commonly understood to be an element that occurs frequently in a text or describes a unique experience that gets at the essence of the phenomenon under inquiry" (p. 89). Across the distinct focus groups and campuses, we specifically focused on themes that highlighted the promotion or hindrance of URMs developing a science identity and scientific self-efficacy.

We thematically coded the transcripts and organized the findings using *NVivo* software (Bazeley 2007). To ensure validity in the coding scheme, we conducted inter-coder reliability checks. The four researchers responsible for coding the data were paired off. The pairs were assigned a randomly selected five- to seven-page section of text that each member coded, and reliability results were calculated by dividing the number of agreements by the total number of passages. Inter-coder reliability for each of the pairs averaged 75.5%. Inter-coder agreements above 70% are deemed acceptable, but above 90% is preferred (Miles and Huberman 1994).

### Limitations

This study presents two distinct limitations. First, using focus group transcripts as the primary data source does not allow for participant observation in the natural setting of the science research program. We rely upon the validity of students' reporting which could be minimized through a more ethnographic approach (Jones et al. 2006). However, we invested our time in collecting data at four separate institutional sites, as opposed to conducting an ethnography of a specific campus, because we saw the benefit of examining how students interpret and experience becoming a scientist in a variety of contexts. Therefore, because this is based on the meaning that underrepresented students construct, a phenomenological approach was warranted.

Second, the purposeful sampling technique restricts the generalizability of our findings in that students were specifically selected for the program based on previous performance and traits, and we do not know how students in general experience science at their respective institutions. Further, we conducted an oversampling of MSIs where less information is known about student engagement in science and resources may be more limited. Given the set of four institutions and relatively small sample size, we cannot claim our findings necessarily will apply across all institutional cultures and student populations. Our purpose in this research is not to identify dominant trends in URM research scientist development, but rather, to explore campuses that have consistently demonstrated success in pursuing this goal. Thus, we intend to identify student experiences that may inform the development of effective practices that other campuses can learn from in becoming more inclusive in science training.

## Findings

In analyzing the focus group transcripts, we identified seven major themes discussed by students regarding their developing interest in scientific research careers, as well as challenges they have faced and continue to encounter along this path. We present only three of these themes to cover issues surrounding the way in which students become a scientist, how they navigate the culture of science, and the role of social stigma in both of these processes.

### Becoming a Scientist

Participants indicated their interest in science as stemming from a multitude of experiences, including: fascination with scientific principles or subject matter; pre-college math and science performance; scientific research exposure once in college (including the interplay between hands-on research and classroom learning) and the development of scientific self-confidence; and overall participation in science research programs. The latter two experiences have significantly contributed to students' desire to attend graduate school, and what is more, obtain a doctorate and pursue a scientific research career.

**Early Interests and Aspirations—**A majority of the participants described their predispositions toward science as occurring before college entry (although, as will be discussed later, the college experience has greatly influenced students' continued interest and retention in these fields). Many students had an initial fascination with some facet of science (e.g., stars or butterflies developing in cocoons), which sparked intellectual curiosity at an early age. As one MIT female explained, "I was just always interested in how things worked and I always… I guess I dreamed of getting to a point where I didn't have to ask people how things worked…so I wanted to get the tools to be able to figure that stuff out on my own…"

These initial interests were frequently coupled with early success in math and science classes. As an MIT male student stated, “I kind of had an interest in math and science just because it came naturally to me.” This perceived aptitude was not exclusively a matter of personal drive, as many students highlighted the integral role primary and secondary teachers played in both nurturing interest in science and validating students’ abilities. As expressed by an MIT female student, “Along the way, I had a couple of teachers, particularly some female teachers, that really encouraged me to get into science and math.” This encouragement offered by teachers perhaps strengthened students’ self-efficacy, encouraging students to eventually pursue science majors in college.

**Research Exposure—**It was clear from focus group discussions that once in college, students were on the appropriate track to major in a BBS field, but lacked the awareness of a scientific research career as a valid long-term option. Yet, for the majority of participants, engagement in undergraduate research—particularly through a structured program—provided in-depth understanding of what a research career would entail while simultaneously supporting students to view themselves as research scientists, both in college and in the future.

Indeed, participants across all focus groups were quick to acknowledge the role of research programs in allowing them not only to gain experience, but to do so at a high level, perhaps higher than what they would otherwise be afforded. According to a male UNM student:

> I mean, it’s not like we wouldn’t ever have been able to get experience in a lab without the MARC or IMSD programs…but…they definitely provide us this research experience…it’s a more directed research experience. Instead of just helping out some dude with his research, we’re being taught this with the intent of us eventually being the ones coming up with these questions, writing these grants, and submitting papers for publication.

Another UNM male student elaborated:

> When I was working in other labs, it would be like, OK, I’d tag along with this graduate student and help him with his project, you know, and get an understanding of what they were doing. But with the MARC program, suddenly I’m conducting my own experiments, trying to figure out how I can answer these questions that I come up with, so it gives you a different research experience.

A final sentiment across groups was the way in which structured programs facilitated a “bridge” between undergraduate research and graduate or professional research.

The interplay between hands-on research and classroom curricula improved student understanding of scientific principles while also keeping students engaged in scientific learning. An MIT male student reflected:

> There’s only so much experience you can get through class…there’s a lot of things you learn through the lab and through your UROP that you didn’t learn doing the [class] lab research…you actually do stuff that’s like in real life, whereas in most classes you only cover concepts, and so you don’t see where those concepts come into play.

A UNM male student expressed a similar sentiment:

> It really sort of transforms the landscape of biological sciences…when you go from reading a textbook and memorizing what you need for a test to trying to think about how you can figure out more, trying to design an experiment and trying to ask the

> appropriate questions about it, figuring out how to tackle it. You know, it changes the way you think about science.

In some cases, research was the driving force for staying in or continuing to pursue a science major. As one UNM male student stated, "…just working in the lab pretty much the last year has been the only reason I've stayed in biology." Another UNM female student shared, "I was involved with an NIH-sponsored program at [another institution], which was my first experience in a lab and it pretty much really got me started on liking science in a big way."

In addition to the complementary dynamic that exists between the classroom and laboratory, students also expressed a major disconnect between coursework and research. That is, they recognized the uncertainties embedded within a research project that typically do not arise with their learning process in classes; yet these uncertainties are what taught students to "think like a scientist." As one UTSA female explained:

> In the teaching lab…I mean, you run an experiment and it always works. It's so nice. It always works. You take biochem lab, you take genetics lab, and you do it, and man, it's going to work. It's been done 50,000 times in the lab… People who have never been in a research lab [can do it]. I think the first time your experiment fails, it's kind of like a shock to every one [of us]. It's kind of like, "What?" Yeah, it makes you learn how to think…

When the experiments *do* work, there are few academic accomplishments the participants described as more satisfying. A female at UTSA, for example, described the learning process:

> [W]hen you're doing your research, …you already know the basis of your project and you get to a point where you start doing your research and you get data, and you're just like, "Yes, I got a baby step," …and your professor's like, "OK, well, go ahead and do this, this, and that," and just add on more, and you're just like, "OK, cool." So you start doing your research and you get more data, then you're so close to publishing. It's just…I don't know, it's thrilling to know that you're able… that you're capable of understanding your research and to produce data that will help out a foundation of [knowledge about] diabetes, for instance…so it's just when you get to a certain point, you get so happy and you just…it's addicting!

**Research Career Goals—**Almost all focus group participants indicated graduate school attendance as important to future educational goals, particularly the completion of a doctorate degree in a science-related field. Yet for some, the early years of college were filled with unease and little understanding regarding what a career in science research would entail. Research exposure introduced and solidified the vision that students shared of what it means to be a scientist. An equally important finding is the way in which students who initially had goals of becoming a medical doctor changed their focus after participating in a structured science research program.

Several students who discovered their love for science in middle and high school tended to gravitate toward medicine for the fact that doctors were a part of their lives. As a UNM female student explained, "…when I was growing up, I don't even think I really knew what a scientist was other than a doctor." Yet once exposed to research, specifically in the programmatic setting, students who came to college pre-med shifted their goals away from medicine in favor of careers in scientific research:

> I actually applied to the MARC program wanting to know, "Should I go into medical school or graduate school?" I was really not sure…but then…once I was in the MARC program…doing research, I liked the research a lot and I also realized

> that there's so much opportunity out there that I didn't realize before, which was a real eye-opener for me. (UNM male student)

Another UNM male student conveyed a similar sentiment:

> I initially wanted to go into medicine just for the whole helping people thing, and then I got accepted into the IMSD program and had the opportunity to do research and found that I actually liked that better than I think I would doing medicine, so that's…why I chose to stick with research.

Several participants also described altruistic but very personal reasons for their interest in research, such as a family member being diagnosed with lupus, diabetes, or cancer. Programs attempt to select students with the greatest potential for research as opposed to interest in a medical career, and some students are obviously still considering their choices. However, it is clear that the experience helps inform their eventual choice.

**Developing Science Identity and Scientific Self-Efficacy Through Research—** Conducting research was frequently cited as a primary activity that not only helped solidify career plans but also cultivated a sense of independence and confidence in scientific inquiry. In the research setting and under the guise of the scientific method, students talked about developing a strong work ethic, patience, and ability to accept failure. The following quotes from two Xavier students illustrate this point:

> [A] real crucial skill that I learned through being in the lab is just that drive, that work ethic that you have to have. (Xavier male student)

> I learned how to fail this summer. I'm not used to failing… As a scientist, you have to learn that sometimes things just don't work. You have to pick up your boots and keep on truckin'. (Xavier female student)

It is clear that both students identify with the traits of being a scientist, and recognize themselves as scientists as a result of their research experience.

In some cases, the research experience that students had under their belts allowed them to feel more self-assured in the classroom setting, allowing them to demonstrate competence, especially when comparing themselves to peers who did not have the same engagement:

> I took a class where [the professor] was teaching all these experimental methods so that you could basically write a paper or a grant proposal. But some of my classmates didn't have any idea what the methods were and I was familiar with most of them, so it helped me succeed in the class, because I was like, "Well, I've done that," so I know exactly why you would do it and how, and they didn't… couldn't comprehend that other than reading a chapter of the textbook. (Xavier female student)

Another student expressed how his research experience enhanced his confidence in pursuing science as a profession:

> [W]hen you're in a lab doing research, you're actually contributing to a project that you can actually see what you have done and when it leads to something, like a publication, then it sort of reaffirms your confidence in science as a profession because you see that you are actually doing something as compared to just being in a class and learning what other people have done. (Xavier male student)

The research setting provided validating experiences and recognition. The ways in which students described being socialized into this setting—including being part of an overarching project team supported by a faculty member—had a significant impact on how students see themselves:

> I had a good experience with my PIs [principal investigators] just because they made me feel like…as an undergrad, you kind of feel like on the bottom of the food chain and they kind of believe in you and say, "Yes, you can do this. I'm giving you this project to do and I know you can do it." So it kind of builds your confidence and just them believing in you makes you feel like you can actually complete the project because you can. (UNM female student)

As the students demonstrate, research experiences coupled with classroom learning reinforce students' interest and determination in the study of science, further shaping their sense of self in their academic environment.

**Program-Specific Support Outside of Research—**We would be remiss not to include the overarching benefits of structured research programs—particularly MARC, MBRS and other NIH-sponsored programs—in the development of students as research scientists. In addition to research experience, participants learned a number of skills they believe are important for graduate school preparation and success in scientific fields. These included GRE preparation classes, seminars on writing one's curriculum vita, direct academic and social support from program staff, and opportunities to present their research.

Each of these activities contributed to students' articulation and confirmation of their career plans as research scientists. Given the multitude of offerings these programs put forth, including research experience, encouragement, mentoring, and nuts and bolts preparation, a UNM male student who was recently admitted to graduate school summed it up nicely saying, "I can't even imagine being accepted to [graduate school] without this program." Indeed, the frequently cited benefits of structured research programs can be seen as an agent for success in institutional cultures that often can dissuade scientific career aspirations.

### Navigating the Culture of Science

The culture of science encompasses a variety of dimensions. It espouses the *way* knowledge is constructed, as well as *how* scientific knowledge is produced and reproduced through normalized practices within scientific fields. Additionally, science culture describes both macro (the field of study as a whole) as well as micro (a local college campus) environments. In the present study, the "culture of science" emerged in focus groups when students described the learning environment. It is imperative to note, however, that while similar themes emerged across institutions, the way science is done on each campus is unique. For example, as one Xavier student proudly stated, "We do science here," which aptly described the ethos at the institution. Further, Xavier students were more likely to describe an institutional expectation of collaboration, which was not necessarily the sentiment expressed by students attending other institutions. While conducting an in-depth cross-case analysis is beyond the scope of this study, we chose to highlight themes that emerged from the student voices across all four campuses. Students tended to describe the campus culture of science in one of three ways: collaborative, competitive, and academically intimidating.

**Collaborative—**When students described the culture of science on their campus as being collaborative, they discussed numerous facets. For instance, they talked about collaboration with and among peers (both within their cohort and with more advanced students), graduate students, and faculty in a variety of circumstances, including course assignments and research projects. A female student from MIT described the support that she receives from her peers:

> The students are really kind of like the support network here. The students really help each other. I know if I needed something and my advisor wasn't going to give

> it to me, I'd definitely go to any of the students, and I know students who are ahead of me, and just talk to them about that.

The majority of students indicated how the curriculum forced them to be collaborative due to a heavy homework or problem-set load. Many expressed the impossibility of an individual working alone to complete the required assignments. On one campus, collaboration is so commonplace that students interpret it as a natural part of their view of the culture of science. A female participant shared:

> It seems like at Xavier, the people have a mentality…like the sharing mentality, so if you're not…if you don't share or if you're not…if you're thinking about number one, they kind of shun you to the side. I mean, because everyone else is in the group, and [if] you think you can work better on your own, we'll let you work on your own. That's how it is here.

Other students went further and spoke about how differences in curriculum foster collaboration. Students at MIT described engineering courses as prescribing and actively encouraging group work, whereas science classes (biology, chemistry) seemed more individualistic.

Another component of student life that is conveyed through collaboration is being able to form support systems as part of the program. A female participant from UNM expressed, "I think academically, too for us, if we're in the same class and they'll come up to me and say, 'Hey, have you looked at this book? It really helps'." A fellow male classmate agreed, "Yeah, it builds a sense of community, which is hard to get as an undergraduate." Different actors on campus (peers, professors, advisors, etc.), played a role in creating a collaborative learning environment for students. Yet, while some students expressed the presence of collaborative science learning environments, many others described the culture of science as being extremely competitive.

**Competitive—**When describing the competitive nature within the culture of science, students highlighted both positive and negative experiences. A number of students referenced how peers in different majors are more competitive than others. For example, they claimed a student who is pre-med is more concerned about his or her grades, and will therefore be more competitive than students who are not aspiring to become a medical doctor. On the other hand, another student described how competitiveness can prove to have a positive effect. A female student from UNM commented on how the program influences her to do well:

> Something that influenced me in science, too, is if you're in a program like this, you start getting to know everyone in the department or in the classes that you're taking, so you're almost embarrassed to do poorly in class, so you work harder. Like you're driven to work harder because you want to be a good student and you want to succeed.

When the competition is not centered on grade comparisons or feelings of needing to outperform each other, students can be motivated by their peers, whom they see as role models, to study harder and perform better. An interesting interplay between this notion of competition and gender is shared by a female student from UTSA: "One person in my lab [is] one of the smartest people I know… I want to be as good as that, so it makes you try harder. I guess I'm kind of competitive in that way, but…I don't know, I guess I want to be better than the guys…you know." This kind of competition becomes a challenge that fosters a greater sense of self-efficacy.

**Academic Intimidation—**Another aspect of the culture of science, academic intimidation, was depicted as a sensation students have when they do not feel on par with what is expected of them. One example is when students recalled the application process for the research programs in which they participate. After rejection from the program following her initial attempt, a female MIT student shared, "So it was very intimidating for me to go out [for the research program], and then once I was rejected I thought, 'What is wrong with me?"' In the classroom setting, several students described not knowing or fully understanding a concept while the professor would state that the concept is "obvious," thus making students feel as though they are ill-prepared for class material.

To overcome this feeling, many students attend office hours on a frequent basis. One participant talked about how students often fail to pose a question within the classroom setting, but a number of students will appear during office hours to ask the professor what he or she meant when the respective remark was made in class. This sentiment is best described by another female student from MIT as follows: "People in organic chemistry don't sit there and ask, 'How did that work?' You wait until office hours, in the quiet, and make sure nobody thinks that you're dumb." An additional facet of academic intimidation is seen in how approachable the professor appears to be in the eyes of students. A female student at MIT admitted:

> I think it's hard to ask for help, especially like…well, all my professors are either White or Asian and it's kind of hard for me sometimes, but I think…yeah, just recently, maybe last year, I started talking to a few of my professors when I…after class…I didn't understand something, but it took me two years to finally do it. It's intimidating.

In this case the student refers to racial differences as a potential barrier, but she must overcome academic intimidation, and build her self-confidence to ask about what she does not know. This contrasts dramatically with the research process, where it is widely accepted that answers are unknown and one must learn from failure.

## Social Stigma

Competitive and academically intimidating cultures of science were not unexpected given the reputation of science teaching and learning processes, as mentioned earlier. Indeed, students further experience and face social stigma, particularly as it relates to their racial/ethnic background and aspirations as scientists. Students in our focus groups identified at least three types of stigma-related challenges they face that mainly refer to external, negative perceptions or judgments that others may hold of them. These include the negative associations stemming from students' involvement in minority-based science research programs, feeling the general need to validate their academic competence as URM students, and the specific need to affirm their identities as science students.

**Racial Stigma and Research Opportunities—**Students' participation in structured research programs, especially those clearly geared toward minorities, presented some of them with a dilemma: while they enjoyed the chance to become more deeply engaged in science research endeavors, they also struggled with the potential stigma of being selected for such programs because of their minority status. Several students at the various campuses expressed the sentiment that their association with such programs seemed to overshadow the consideration of their own academic qualifications for research opportunities. As one UNM male explained:

> When you go to somewhere else and [you say], "I did this research and was part of this minority program," they might say, "Well, no wonder you got such good research. Of course you did because you're a minority."

The assumption that URM students' access to research and other academic opportunities depends more on their identity than on their academic qualifications was reflected in the piece of advice that another student from UNM received from a faculty member. He shared, "I had a professor that…was encouraging me…he was like, 'You need to ride that [Hispanic] surname for everything that it's worth'."

Interestingly, at UNM in particular, one of the campus research programs available to minorities kept its longstanding acronym, IMSD, but recently changed the program title from Initiatives for Minority Student Development, to Initiative to Maximize Student Diversity. The same UNM student acknowledged this made a meaningful difference to him:

> [T]hose two programs that are here for research, IMSD and MARC, they both are…minority programs, so it felt like we were getting an advantage compared to other students, but when [IMSD] changed their name…[it] made me more comfortable and maybe it would make new prospective [students] more comfortable…in applying to such a program…[because] when you have a program that includes everybody, it's sort of like what you did is equal to what someone else did.

Another UNM student revealed similar feelings about the IMSD program title change when she admitted, "Well, that's one thing I like about this group, is that they don't only accept Hispanics from UNM. They accept every race, so I guess it's truly diversifying…"

Even students who engaged in research experiences not necessarily focused on URMs in the sciences felt they were specially targeted for the sake of diversification. For example, a student from Xavier shared her belief that she was accepted into a summer science research program outside of her home campus on account of what she represented:

> I did a research program with…[a university] in Ohio and one of the things they were trying to do is enhance their diversity of the programs, so…one of the… reasons I was accepted was because…I go to an HBCU and I'm a minority and that played a factor. They probably never had someone from an HBCU…

Along the same lines, a female student from UNM talked about the different perceptions that others have had of her involvement in structured research opportunities:

> [H]ere in New Mexico, when I go back home or whatever, when I tell people, "Oh, I'm in a minority program that basically supports me to do science," they're like, "That's awesome. That's really good." But I spent the summer in DC, and…I worked with an Anglo girl who was there and basically paid her way there and the only reason she was there is because she knew someone who knew someone, and I told her, "Oh, I'm in this…minority summer research program," and she's like, "Yeah, well, you're lucky you're a minority, you could say that on a piece of paper so you could get in."

The student went on to say that despite receiving mostly positive reactions from family and friends who have learned about her experience in IMSD, she also recognized that others, like the peer she met in DC, may feel "disadvantaged" by her chance to take part in minority-based research programs.

From the students' perspectives, concerns about being token representatives or that their involvement in minority programs amounted to pathways toward second-rate academic success sometimes led them to question the very existence of the programs. As one undergraduate at UNM expressed, "I think it's hypocritical for someone to say, 'Well, we want you guys to stop picking only old White men, so we're going to pick only women and Hispanics'…" In contrast, another UNM student spoke about the need to continue such programs, given the various factors such as ethnicity, gender, and socioeconomic status that might affect students' achievement in the sciences. She said, "These programs still support people who need it…[and] who don't have the means [otherwise to be here]." And a third UNM student explained her view in support of minority-serving programs in this way:

> I think I read some statistics that say primarily undergraduates in biology are women and not only that, there's huge ratios of minorities that are attracted to this field, but again, it's not reflected and somehow you feel a little strange when you're the only girl in the room or you feel a little strange when you're the Black guy in the White room, you know, and that might be a really big deterrent for people to go into these fields because they're…we're so human at the end of the day and we want to feel like we're amongst a group of people that are accepting or that are already integrating people like ourselves into those groups. Maybe it's some other outside factor that is independent of race and gender profiling or whatever, but it at least is worth a shot to have programs that support maybe some kind of diversity happening in these old White guy clubs, you know.

Regardless of their perspective, students across all the campuses described a range of experiences with social stigma specifically associated with being a minority in science.

**Racial Stigma and Scientific Self-Efficacy—**URM students in our focus groups reported facing obstacles of limited educational access and skepticism regarding their intellectual talents, leading them to feel varying intensities of stigma that may put them at risk for stereotype threat, or the fear that one will confirm negative perceptions of one's racial group based on individual academic performance (Steele 1997). Students can be primed in different ways to the sensitivities of race and racism. For example, one student from UTSA explained that even as early as high school, she observed that she and other Latina/os were not usually the ones invited to her school counselor's office for college guidance, which made her feel discouraged to the point where she wanted to drop out of high school:

> I was so frustrated with the whole system I just…I wanted to quit high school and my mom made me go to the alternative school and I finished two years in a year and was just out of there, so when I came here [to UTSA], I had had the most lousy education ever, so it took awhile to get caught up with everybody else…

A student at Xavier spoke of the frustrations he has had in dealing with others who underestimate the value of his education at an HBCU. While he attended another institution after Hurricane Katrina, he found himself talking about different types of campuses with peers at his surrogate university:

> [T]hey brought up the difference between HBCUs and Ivy League schools or regular schools and that's when it first hit me I guess…generally HBCUs may not get as much funding as state [schools or other places], so they're not as equipped as other schools and you see that. When I went from…the lab in Xavier's classroom…to [a university in Texas] and I go to the lab in their classroom, they [had] an incubator almost the size of half of our class [at Xavier]…so there's definitely a difference. You know, you see the difference in funding and how that plays a role in educational quality, but at the same time, with what we have, Xavier does give you a quality education and people tend to look over that, you know, when the fact that it's an HBCU comes into play just because [of] the general stigma of what an HBCU is.

Another male student explained the uniqueness of attending an HBCU for him by recounting his transfer to Xavier from a predominantly White university:

> I felt so disconnected from everybody, not necessarily because it was a racial difference, but just the motivational factor. I didn't feel motivated, I felt as if I was just a social security number, so I decided to come to Xavier and that's when I felt at home, you know, because I got individual attention, I got motivation, I was able to see professors that were African American, biochemistry PhD professors, people that look like me, which motivated me to say, "OK, I can do this. It's possible for me not only to get an undergraduate degree, but also to pursue a higher level degree," so it's the motivational factor that I would say an HBCU provides.

For these two students and others at Xavier, they balanced the stigma of attending a minority-serving institution with fewer resources with the academic and social support system that such a campus offers, and this reaffirms findings from previous research on HBCUs (Allen 1992; Allen et al. 1991; Chang et al. 2008). Many students in the wake of Hurricane Katrina had the opportunity to go elsewhere to continue their college education, and these students chose to return to their home campus Xavier.

The message that minority students are somehow less deserving of educational opportunities, or that they must provide proof of their academic abilities, also resonated with several undergraduates at MIT. One male student shared, "I've had discussions where people have said that sometimes minorities go for their PhDs just for validation [of their educational ability]." Similarly, a fellow student added:

> [B]ecause I am a minority student, I feel as if I need the validation. Anybody else would not need it. You know, nobody else has this feeling of, "You know what? My opinions aren't going to be listened to…unless I get the PhD. (MIT male student)

A third MIT peer commented about her reasons for wanting to pursue an advanced degree to demonstrate her intellectual worth:

> Currently I work in the Graduate Student Office…and so I see the other side. I see departments where they're asked, "Why don't you have any minority students this year?" and [the response of] "Oh, well, you guys didn't give us a good candidate." And even though you know that can't be true,…when you see the other side, you know that there is somehow, somewhere, there's some qualification that minorities have to have that other people don't have and … it's not stated and it's not talked about, but it's still there.

For other MIT students, they felt even more immediate anxieties about needing to assert their academic qualifications among science peers. As one female student put it:

> [If people in class] accidentally see one of your grades,…then the word around the street is that you're smart, but if you're not smart, then I guess you always feel that pressure, but I tend to go into the classes and do well on something and then everyone latches onto me, but before they knew, they assumed that I didn't know.

A male MIT student shared his experience as well by saying, "I like to let people sit back and form their judgments about me and then I just blow them out of the water, because their expectation was so low…I like to have them be wrong." Over time, the pressure to constantly have to prove oneself academically worthy, especially in the sciences where minorities are severely underrepresented, may either put a damper on URM students' academic efforts, or motivate them to excel even further (see Major and O'Brien 2005), as these last two students illustrate.

**Science Stigma—**Although not as prominent as the race-related stigma, the stigma attached to aspirations of wanting to be a scientist also played a role in students' sense of science identity and scientific self-efficacy. From not being expected to excel in the sciences, to not having full familial support, to being branded as a “science nerd,” several students expressed the difficulties of developing a solid science identity. For instance, a male student from UNM recounted:

> In my own experience, I find that…where I was raised, you weren’t expected to get a PhD or anything like that. Just you were expected to work hard. You know, the best you could do was maybe get a job with the government, but that expectation wasn’t there. In fact, you were expected not to do that well…and everything was like a pecking order and then the guy that always got the straight A’s, he was the one that was going to go to med school or get his PhD or go into engineering, but that expectation was never there [for me]. And then when I started going to college, I started getting a lot more self-confidence in myself, especially when I saw how well I did in my classes.

A female UNM student spoke about having to explain to her family her goals to pursue an advanced degree in science:

> “Why would you want to be in school that long? That’s too much hard work. Why would you do that?” is what I get from my family mostly, other than my mother…she’s gone to college, she’s the only one that’s gone to college…who can see that I should do more…more school is better, but I get a lot of the just…they don’t understand why I would want to do it.

However, these students received substantial recognition from meaningful others in the program to sustain their interest. Carlone and Johnson (2007) suggest that recognition from meaningful scientific others (peers and faculty) and non-scientists (family and peers) hinges on whether the positive recognition outweighs the negative. When negative recognition prevails, students either redefine what it means to be a scientist or seek other social networks.

A male student from UTSA commented that people “who don’t know” about the life of a scientist (e.g., attending conferences to present research), will label him negatively, despite their own use of science and technology. He elected to develop a new social network:

> [T]hey label us “geeks,” right, but yet they turn…around and they like electrical engineering, they like their cell phones and they love their iPods, they love their Xboxes, they couldn’t live without them, and their plasma screens… But then they turn around…and they say, “Hey, you geek…” So my friends there, that I used to have back in the barrio, they don’t talk to me anymore, “Oh, you think you’re too good…” I lost all my friends, you know, and that’s a sacrifice that I made and I…of course, fortunately there are many more people to make friends with so, so my friends changed…the type of friends I had changed.

Other students experienced the science stigma as general confusion over why they would choose a science career path. A male Xavier student shared, “I guess in general with people, they seem to kind of have a puzzled look on their face when I tell them what I want to do. It’s like, ‘OK, a chemist. Really? Really?”’ Another Xavier student talked about the reactions she has seen from friendly acquaintances:

> [T]he people at the beauty shop, they’re like, “So you’re going to be a doctor, right?” I’m like, “Yeah, I’ll be a doctor [as in PhD]. Now if you get sick, I can’t help you. I mean, maybe I could synthesize some drug, and that’s a big maybe, but outside of that, you should go to the hospital,” and they’re like, “Oh, OK.” It’s like they don’t understand.

In response to external criticism and misunderstanding, it becomes clear that students must find ways to reinforce their developing science identity. For example, to counteract negative perceptions or misunderstandings about being a scientist, students turn to the support they receive from the structured research programs in which they participate. As one UNM female described it:

> [I]t's kind of nice to have this group that they know what you're doing, they understand research, because I can go home and tell my mom, "This is what I'm working on," but she's not going to understand anything about…not even really science. They just don't understand, so it's nice to have the support.

Another female student from UNM summarized the benefits of her research program participation in this way:

> Getting oriented is incredibly difficult and you need somebody or actually you need a group of people to really first care enough to get you into it and second, show you exactly what you need to do and help you every step of the way, and that means editing letters, that means teaching classes that help you take the tests, getting into the mindset, because we're in New Mexico, this is a unique…you know, all states are unique, but New Mexico specifically has the highest percent minorities than… than any other group, right, so inherently we need programs like this… There's not a lot out there, so the question of whether or not these programs are supporting can be answered easily "yes," but on top of that, we might want to ask, "How many more programs like this can we get started or how much can we help these programs grow?" That really should be the question that's being asked I think.

The participants in our focus groups bring a key issue to the forefront: minority students frequently deal with social stigma, which may then exert influences on URM students' experiences as scientists in training. Students from MSIs reported stigma from a variety of sources, and even students who felt pride in attending an HBCU known for its science focus also experienced stigma in interactions external to the institution. That is, underrepresented students are targets for social stigma regardless of their participation in programs. The programs provide a critical mass of peers and faculty role models who are also from racially diverse groups, which help offset the effects of stigmatization to focus on academic excellence.

## Discussion

Underrepresented students' stories about learning to become a scientist leaves much hope for the future, while also providing a significant wake-up call about the obstacles they have overcome to begin to see themselves as scientists. Although some students display the dispositions to become a scientist since an early age ("it came naturally to me") and exhibit inquisitiveness about how the world works, many find they resonate with the "work ethic" or necessary drive and desire to get the tools to answer their own questions once they have research experience in college. Another disposition many of the students demonstrated is a form of resilience in the face of adversity and a determination to achieve their goals. Faculty can recognize these traits that are necessary for success, yet we currently have no way of identifying or nurturing these dispositions except in one-on-one advising or mentoring relationships.

The "weeding out" that occurs in introductory courses does more to identify students' preparation prior to college than to identify the dispositions among students for scientific work. One of the institutions, MIT, implemented a policy of having the first semester of college without grades, giving students an opportunity to adjust to the academic culture, as well as time to review those foundational scientific principles necessary to continue along their path. Students at Xavier, the only HBCU in our study, tended to describe a unique “culture of science” that was very supportive and collaborative, especially within the classroom. In addition, students at this campus were able to develop their science identity at the same time that they maintained their racial identity. This provides further insight into the link between a science identity and racial/ethnic identity (Carlone and Johnson 2007). In the future, comparative case study analyses will shed more light in the distinctions in practice that might serve to expand and diversify the scientific workforce.

Students also demonstrated a high degree of scientific identity that included a sense of competence, ability to perform, and recognition, and we acknowledge that the sample was a group of students that were selected for a program (with GPA criteria for the MARC program) and subsequently best positioned to be successful in science. Bandura (1997) states external expectations are key in “coercing” individuals to place themselves in situations that may exceed one’s capabilities, and that an individual’s self-efficacy and behavior can deflect any negative ascription. Students provided many examples throughout their high school, college, and research experiences in which they placed themselves in situations or environments where they were potentially vulnerable but emerged successful: the student who had attended an alternative high school and had to “catch up” in college, the stretching another had to do to overcome academic intimidation to ask professors questions, and several students who went to other institutions in the wake of Hurricane Katrina to continue their academic work. At the same time, the structured research programs also required students to stretch their capabilities through engagement in research on campus and experiences in new environments during the summer, including conducting research in another institution (as part of the MARC program), or research in industry as part of programs with pharmaceutical companies. Each challenge and success they experienced further reinforced their performance and competence as scientists.

Students across all the campuses, however, also described a range of experiences with social stigma specifically associated with being a minority in science. However, there were nuances in their indicating the source and situations. While students disagreed on one campus about the need for a program to equalize opportunity in science, some had personally encountered White majority resentment of the opportunity or had internalized some of this resentment—making at least one student more comfortable with more race-neutral programs. It is important to note that this was evident on only one of the campuses that had changed its program name and involved a more “diverse” group of students in the program. On the campus without a minority-targeted program, however, it was evident that there was a much lower participation rate in research among underrepresented students and students spoke of stigma encountered throughout their education. In analyzing the range of quotes, students typically encountered situations of stigma regardless of involvement in a minority program, with some students more likely to encounter these in experiences outside of college where they also were aware of resource differences in research settings. These different situational contexts provide some perspective on the matter of race in science and reinforce the idea that racial dynamics inevitably enter into the academic and social environment of science undergraduates (Carlone and Johnson 2007; Fries-Britt 1998; Oyserman and Swim 2001; Shih 2004; Treisman 1985).

As a result, students navigated social stigma differently. Some were more vulnerable to the stereotyping and concerned that others thought their involvement was an “unearned” privilege, while others with a high degree of self-efficacy seemed to take social stigma they typically encountered in stride (“I like to prove them wrong”). Overall, there was less concern with the stigma of being a scientist (“the geek” or “bug lady”) from non-science peers or their communities, as they accepted this as part of their identity of becoming a scientist. Consistent with previous research on URM structured undergraduate research programs, administrators and staff of structured programs aiming to cultivate greater levels of engagement and success of URM science undergraduates must be aware of such potential influences on students' sense of identity and self-efficacy and play an active role in supporting their academic development as research scientists with distinct racial identities (Barlow and Villarejo 2004; Dirks and Cunningham 2006; Fries-Britt 1998). Findings from this study highlight that focusing only on the non-racial aspects of scientific learning and research is not sufficient to reduce the levels of stigma that often target URM students. Thus, it may be useful for science faculty and program staff to develop strategies to offer recognition that may counteract negative stigma as a component of these URM undergraduate research programs.

Students expanded our understanding of aspects of the culture of science in that they experienced science as collaborative and competitive, intimidating and disempowering, as well as exciting and empowering. These dichotomies appeared to diverge along the fault lines between how they learned science in classrooms and how they learned science through research conducted with faculty in their programs. The research experience allows students to experience the collaborative and empowering culture of science. Actual scientific research is conducted in teams, with different levels of expertise, allowing all to invest and gain ownership in the research product. The laboratory experience was key in motivating students to find the tools they needed, acquiring knowledge about the scientific method, as well as providing a real-world connection to the concepts learned in class. Consistent with previous literature, it also helped them solidify their career plans as research scientists (Kinkead 2003; Lopatto 2004). Further, the probabilities of failure are more widely accepted among faculty and budding scientists conducting research, while the classroom is less forgiving with greater social (labeled as "smart" or not) and academic consequences.

Also evident in students' stories is a more elevated footing for undergraduates. Students interacting with professors in the research process sensed that these mentors believed they were capable, allowing them to achieve recognition (Carlone and Johnson 2007), as compared with their relationship with professors in the classroom. Students also spoke of collaborating with peers outside of class to accomplish their academic work, similar to what Treisman (1985) discovered among Asian American students at the University of California, Berkeley. Further, the kinds of competition the students in these programs often talked about were motivating as opposed to discouraging—not unlike a sport, where one trains with someone better than oneself in order to improve one's own abilities. These elements that are part of the culture of science that take place among successful students in structured research programs ought to be transferred to science classrooms. By creating science classroom environments that are more accepting of learning through trial and error, or that are grounded in more collaborative team work—as research experiences often are—colleges and universities can make progress in aligning undergraduate research, course-work, and their institutional culture of science in such a manner that comprehensively supports underrepresented and majority students alike. This perhaps may be the most important implication for policy and practice that arises from our study.

As educators we have to redefine both the "way science is done" in terms of teaching and learning, and our notions about who can do science. It calls for actively engaging in a paradigm shift of inclusive excellence in order to diversify science. The highly motivated, underrepresented students who participate in undergraduate research programs serve as prime examples of not only who can do science, but who will do science in the future.

## Acknowledgments

This study was made possible by the support of the National Institute of General Medical Sciences, NIH Grant Number 1 RO1 GMO71968-01. This independent research and the views expressed here do not indicate endorsement by the sponsor.

## References

Abraham JP, Lujan SS, López EE, Walker MT. Graduating students' perceptions of outcomes of college experiences at a predominantly Hispanic university. Journal of Hispanic Higher Education. 2002; 1(3):267–276.

Allen WR. The color of success: African-American college student outcomes at predominantly white and historically black public colleges and universities. Harvard Education Review. 1992; 62(1):26–44.

Allen, WR.; Epps, EG.; Haniff, NZ. College in Black and White: African American students in predominantly white and historically black public universities. Albany, NY: State University of New York Press; 1991.

American Association of Colleges & Universities. Making excellence inclusive. 2007. Retrieved June 2007 from www.aacu.org/inclusive_excellence/index.cfm

Anaya G, Cole D. Latina/o student achievement: Exploring the influence of student-faculty interaction on college grades. Journal of College Student Development. 2001; 42(1):3–14.

Astin, AW. What matters in college? Four critical years revisited. San Francisco, CA: Jossey-Bass; 1993.

Augustine, NR. Rising above the gathering storm: Energizing and employing America for a brighter economic future. 2005. Retrieved March 19, 2008 from http://www.commerce.senate.gov/pdf/augustine-031506.pdf

Bandura, A. Self-efficacy: The exercise of control. New York: W.H. Freeman and Company; 1997.

Barlow AEL, Villarejo M. Making a difference for minorities: Evaluation of an educational enrichment program. Journal of Research in Science Teaching. 2004; 41(9):861–881.

Bazeley, P. Qualitative data analysis with NVivo. Thousand Oaks, CA: Sage Publications; 2007.

Biological and Biomedical Sciences. African-American baccalaureate. Diverse. 2006; 23(8):54.

Bronowski, J. Science and human values. New York: Harper & Row; 1972.

Carlone HB, Johnson A. Understanding the science experience of successful women of color: Science identity as an analytic lens. Journal of Research in Science Teaching. 2007; 44(8):1187–1218.

Carnavale, AP.; Fry, RA. Crossing the great divide: Can we achieve equity when generation Y goes to college?. Princeton, NJ: Educational Testing Service; 1999.

Center for Institutional Data Exchange Analysis. 1999–2000 SMET retention report. Norman, OK: University of Oklahoma; 2000.

Chang MJ, Cerna OS, Han J, Sáenz V. The contradictory roles of institutional status in retaining underrepresented minorities in biomedical and behavioral science majors. The Review of Higher Education. 2008; 31(4):433–464.

Cole D. Do interracial interactions matter? An examination of student-faculty contact and intellectual self-concept. Journal of Higher Education. 2007; 78(3):248–272.

Cole D, Espinoza A. Examining the academic success of Latino students in science, technology, engineering, and mathematics (STEM) majors. Journal of College Student Development. 2008; 49(4):285–300.

The College Board. 2005 College-bound seniors: Total group profile report. 2005. Retrieved February 25, 2008 from http://www.collegeboard.com/prod_downloads/about/news_info/cbsenior/yr2005/2005-college-bound-seniors.pdf

Contreras, FE.; Malcolm, LE.; Bensimon, EM. Hispanic-serving institutions: Closeted identity and the production of equitable outcomes for Latina/o students. In: Gasman, M.; Baez, B.; Turner, CSV., editors. Understanding minority institutions. Albany, NY: SUNY Press; 2008. p. 71-90.

Council of Graduate Schools. Graduate education: The backbone of American competitiveness and innovation. A report from the council of graduate schools advisory committee on graduate education and American competitiveness. Washington, DC: Council of Graduate Schools; 2007.

Creswell, JW. Research design: Qualitative, quantitative, mixed methods, approaches. 2. Thousand Oaks, CA: Sage Publications; 2003.

Dirks C, Cunningham M. Enhancing diversity in science: Is teaching science process skills the answer? CBE—Life Sciences Education. 2006; 5:218–226. [PubMed: 17012213]

Driver R, Asoko H, Leach J, Mortimer E, Scott P. Constructing scientific knowledge in the classroom. Educational Researcher. 1994; 23(7):5–12.

Epstein, D. So that's why they're leaving (Inside higher ed.). 2006 Jul 26. Retrieved February 2, 2007 from http://insidehighered.com/news/2006/07/26/scipipeline

Fries-Britt S. Moving beyond Black achiever isolation: Experiences of gifted Black collegians. The Journal of Higher Education. 1998; 69(5):556–576.

Gándara, P.; Maxwell-Jolly, J. Priming the pump: Strategies for increasing the achievement of underrepresented minority undergraduates. New York: The College Board; 1999.

Harding, S., editor. The 'racial' economy of science: Toward a democratic future. Indianapolis, IN: Indiana University Press; 1993.

Huang, G.; Taddese, N.; Walter, E. Entry and persistence of women and minorities in college science and engineering education. 2000. Retrieved February 25, 2008 from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2000601

Hurtado, S.; Cerna, OS.; Chang, JC.; Sáenz, VB.; Lopez, LR.; Mosqueda, C., et al. Aspiring scientists: Characteristics of college freshmen interested in the biomedical and behavioral sciences. Los Angeles, CA: Higher Education Research Institute, UCLA; 2006.

Hurtado S, Han JC, Sáenz VB, Espinosa LL, Cabrera NL, Cerna OS. Predicting transition and adjustment to college: Minority biomedical and behavioral science students' first year of college. Research in Higher Education. 2007; 48(7):841–887.

Hutchison CB, Bailey LM. Cross-cultural perceptions of assessment of selected international science teachers in American high schools. Cultural Studies of Science Education. 2006; 1:657–680.

Jones, SR.; Torres, V.; Arminio, J. Negotiating the complexities of qualitative research in higher education: Fundamental elements and issues. New York: Routledge; 2006.

Kardash CM. Evaluation of an undergraduate research experience: Perceptions of undergraduate interns and their faculty mentors. Journal of Educational Psychology. 2000; 92:191–201.

Kinkead J. Learning through inquiry: An overview of undergraduate research. New Directions for Teaching and Learning. 2003; 93:5–17.

Laden BV. Hispanic-serving institutions: What are they? Where are they? Community College Journal of Research and Practice. 2004; 28:181–198.

Lewis BF. A critique of the literature on the underrepresentation of African Americans in science: Directions for future research. Journal of Women and Minorities in Science and Engineering. 2003; 9:361–373.

Li, X. Characteristics of minority-serving institutions and minority undergraduates enrolled in these institutions. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education; 2007.

Lopatto D. The essential features of undergraduate research. Council on Undergraduate Research Quarterly. 2003; 23:139–142.

Lopatto D. Survey of undergraduate research experiences (SURE): First findings. Cell Biology Education. 2004; 3(4):270–277. [PubMed: 15592600]

Mabrouk, PA.; Peters, K. Student perspectives on undergraduate research (UR) experiences in chemistry and biology. 2000. Retrieved February 25, 2008 from http://www.chem.vt.edu/confchem/2000/a/mabrouk/mabrouk.htm

Major B, O'Brien LT. The social psychology of stigma. Annual Review of Psychology. 2005; 56(1): 393–421.

Malcolm, LE. Unpublished doctoral dissertation. University of Southern California: 2008. Accumulating (dis)advantage: Institutional and financial aid pathways of Latina/o STEM baccalaureates.

Miles, M.; Huberman, M. Qualitative data analysis: An expanded sourcebook. Thousand Oaks, CA: Sage Publications; 1994.

National Institutes of Health. Research on interventions that promote research careers, RFA-GM-08-005. 2007. Retrieved August 2007, http://grants.nih.gov/grants/guide/rfa-files/RFA-GM-08-005.html

National Science Foundation, Division of Science Resources Statistics. Women, minorities, and persons with disabilities in science and engineering (NSF 07–315). Washington, DC: National Science Foundation; 2007.

National Science Foundation, Division of Science Resources Statistics. Women, minorities, and persons with disabilities in science and engineering (NSF 04–317). Washington, DC: National Science Foundation; 2004.

Nicholas D. Making more minority scientists. Environmental Health Perspectives. 1997; 105(2):174–177. [PubMed: 9105790]

Outcalt CL, Skewes-Cox TE. Involvement and satisfaction: The human environment at HBCUs. Review of Higher Education. 2002; 25(3):331–347.

Oyserman D, Swim JK. Stigma: An insider's view. Journal of Social Issues. 2001; 57(1):1–14.

Pascarella, ET. College environmental influences on learning and cognitive development: A critical review and synthesis. In: Smart, J., editor. Higher education: Handbook of theory and research. Vol. 1. New York: Agathon; 1985. p. 1-61.

Provasnik, S.; Shafer, LL. Historically black colleges and universities, 1976 to 2001. Washington, DC: U.S. Department of Education, National Center for Education Statistics; 2004.

Sabatini DA. Teaching and research synergism: The undergraduate research experience. Journal of Professional Issues in Engineering Education and Practice. 1997; 123:98–102.

Schneider, B. Explaining the unrealized aspirations of racial and ethnic minorities. In: Campbell, G.; Denes, R.; Morrison, C., editors. Access denied: Race, ethnicity, and the scientific enterprise. Oxford, England: Oxford University Press; 2000. p. 174-187.

Schuman, H.; Steeh, C.; Bobo, L.; Krysan, M. Racial attitudes in America: Trends and interpretations. Cambridge, MA: Harvard University Press; 1997.

Seymour, E.; Hewitt, NC. Talking about leaving: Why undergraduates leave the sciences. Boulder, CO: Westview Press; 1997.

Seymour E, Hunter A, Laursen S, Deantoni T. Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. Science Education. 2004; 88:493–534.

Shih M. Positive stigma: Examining resilience and empowerment in overcoming stigma. The ANNALS of the American Academy of Political and Social Science. 2004; 591(1):175–184.

Steele CM. A threat in the air: How stereotypes shape intellectual identity and performance. American Psychologist. 1997; 52(6):613–629. [PubMed: 9174398]

Steele CM, Aronson J. Stereotype threat and the intellectual test performance of African Americans. Journal of Personality and Social Psychology. 1995; 69(5):797–811. [PubMed: 7473032]

Treisman, PU. Unpublished doctoral dissertation. University of California; Berkeley: 1985. A study of the mathematics achievement of Black students at the University of California, Berkeley. Professional Development Program

U.S. Department of Education, National Center for Education Statistics. Hispanic serving institutions: Statistical trends from 1990 to 1999. Washington, D.C: Author; 2002.

Vetter, BM. The next generation of scientists and engineers: Who's in the pipeline?. In: Pearson, W., Jr; Fechter, A., editors. Who will do science? Educating the next generation. Baltimore, MD: Johns Hopkins University Press; 1994. p. 1-19.

Yin, RK. Case study research: Design and methods. 2. Thousand Oaks, CA: Sage Publications; 1994.

Zamani EM. African American women in higher education. New Directions for Student Services. 2003; 104:5–18.