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Barricades, Bridges, and Programmatic Adaptation: A Multi-campus Case Study of STEM
Undergraduate Research Programs

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Abstract

In this study, we explored data drawn from case studies of five universities across the United States. The sample included focus groups with seventy students and interviews with sixteen faculty and administrators involved in undergraduate research programs. Our findings contribute to a better understanding of how undergraduate research programs help students overcome barriers to persistence in science, technology, engineering, and mathematics (STEM) fields. We found that the structured research programs at each of the campuses not only adapted to students' needs by attending to the practical barriers they encountered, but also facilitated a feeling of increased social support, a better understanding of scientific research, and motivation for graduate studies in STEM.

Introduction

The NSF (2009) reported that underrepresented racial minorities (URM) make up 22.7% of the 18-to 24-year-old age group (traditional college-going age) in the U.S. but earned only 13.7% of all bachelor's degrees in science, technology, engineering, and mathematics (STEM) fields. In comparison, white students make up 61.4% of the same age group and earned 65% of STEM degrees. This discrepancy in degree attainment may not necessarily be due to the perceived lack of motivation and interest of URM students in science. It appears that an equal percentage (44%) of African American and White college-bound high school students intend to major in STEM fields (College Board, 2005); however, retaining these students in STEM is a major challenge, as only 27% of URMs, compared to 46% of white students, who intend to complete a science or engineering major actually do (Huang, Taddese, & Walter, 2000).

Scholars have found that a number of factors negatively influence persistence among students of color in STEM majors including negative racial experiences (Chang, Eagan, Lin, & Hurtado, in press; Seymour & Hewitt, 1997; Smith, 2003), highly competitive academic environments (Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009), inadequate program support (Seymour & Hewitt, 1997), and institutional selectivity (Chang, Cerna, Han, & Sàenz, 2008; Chang et al., in

press; Hurtado et al., 2007). Undergraduate research programs, however, have been found to mitigate some of these challenges and may increase student persistence in STEM disciplines (Barlow & Villarejo, 2004; Hurtado et al., 2009; Perna et al., 2009). Given the positive outcomes associated with early participation in research, we sought to explore how structured undergraduate research programs enable STEM students to overcome barriers to persistence while increasing their motivation to pursue graduate programs and careers in STEM.

Literature Review

Persistence in STEM majors

A variety of factors have been associated with successful persistence and graduation in STEM majors. Mentoring has been cited as one factor that contributes to the success of students pursuing these degrees. Packard (2004) found that mentoring provides STEM students with the social capital necessary to succeed while helping them to develop their science identity. Beyond mentoring, Perna et al. (2009) found that for African American women at one HBCU, faculty encouragement was extremely important for their success in STEM majors. Women in the study felt as though faculty members believed in their abilities and transformed the curriculum and pedagogical practices in order to ensure their success (Perna et al., 2009). Maton and Hrabowski (2004) also reported that for students in the Meyerhoff Scholars Program, a support program for minority students in STEM majors, faculty support, motivation, and advising were crucial to their success. For Latina/o STEM students, Cole and Espinoza (2008) found similar results and concluded that faculty support and encouragement are significantly related to average GPA. Another important factor related to persistence in STEM majors is participation in supplemental academic support opportunities. Perna et al. (2009) concluded that academic and career support, early warning systems, and peer tutoring helped African American women in STEM succeed.

Bonsangue and Drew (2006) also claimed that out-of-class support programs, such as supplemental instruction, increase the persistence of URMs in math and science courses.

In addition to positive factors that contribute to the persistence in STEM majors, researchers have examined barriers to retention in these fields. In examining the retention of URM students in STEM disciplines, White, Altschuld, and Lee (2006) argued that obligation to community and responsibility to family should be considered important factors influencing persistence. In an attempt to develop an instrument to measure cultural values that may affect STEM retention, White et al. (2006) concluded that obligation to community and responsibility to family accounted for nearly 50% of the variance in the instrument. For African American women in STEM, Perna et al. (2009) cited four types of challenges including: academic, psychological, social, and financial. The academic rigor of STEM coursework left some of these women doubting their abilities and struggling to maintain social relationships with non-STEM majors. Crisp, Nora, and Taggart (2009) also concluded that academic challenges may contribute to the departure of Latina/o STEM students. They found that enrolling in Algebra I or Biology I the first semester was a negative predictor of earning a STEM degree (Crisp et al., 2009). Despite the research that has focused on the persistence of STEM students, the literature focusing on URM STEM students is relatively scant. Thus the current study will contribute to this burgeoning body of knowledge.

Undergraduate Research Programs

Undergraduate research programs have been found to be related to persistence and a number of other positive outcomes for STEM students. Chang et al. (2008) concluded that science students who participated in health science research programs during their first year increased their likelihood of persisting in their major by 60%. Hurtado et al. (2008) found that

engagement with faculty and peer networks were important indicators of participation in structured research programs, which may help students adapt to and persist in biomedical and behavioral research careers. In a study examining the outcomes of participation in a biology scholars program, Barlow and Villarejo (2004) found that students who participated in voluntary undergraduate research were more likely to graduate. Their findings showed that student researchers were four times more likely to graduate in the biological sciences and seven times more likely to graduate in biology with a 3.0 or greater cumulative GPA compared to students in the same biology scholars program who did not participate in research. In another study, Lopatto (2004) found that over 90% of study participants reported that their research experience sustained or increased their interest in graduate education. Similarly, some participants in the Meyerhoff Scholars program at UMBC indicated that research internships and mentorships increased their desire to obtain a PhD (Maton and Hrabowski, 2004).

Another important outcome of participation in undergraduate research programs is an increased commitment to a career in STEM. For example, Perna et al. (2009) reported that in addition to the financial opportunities afforded to students through participation in research programs, students reported an increase in their interest in STEM-related careers. MacLachlan (2006) also found that for African American students, participation in structured research enhanced their commitment to a career in STEM, despite their initial interests in the field. Seymour et al., 2004 conducted a series of focus groups with undergraduate science students to learn about the benefits of participation in research experiences and discovered that early exposure to research helped students to clarify, confirm, and refine their career goals. These studies and several others (Bauer & Bennett, 2003; Hathaway, Nagda, & Gregerman, 2002) have focused on the benefits of participation in undergraduate research programs; however, many of

the studies have been localized efforts often used as an evaluation tool for a single program.

This study will attempt to fill this gap in the literature by including the findings of a series of focus groups conducted at five different campuses.

Preparation for Graduate School

Many of the factors that have emerged in previous research as influencing STEM majors' persistence and degree attainment at the undergraduate level continue to contribute to their preparation and aspirations for graduate school. Prior academic achievement at the undergraduate level has consistently been noted as one of the strongest predictors of students' preparedness and enrollment in graduate programs (Ekstrom, Goertz, Pollack, & Rock, 1991; Millett, 2003; Zhang, 2005). In examining the success of URM students attending graduate school, Nettles (1990) reported that a lower quality of undergraduate preparation among African American and Latina/o students accounted for some of their difficulty in transitioning from undergraduate to graduate education. Institutional selectivity has also been found to affect URM students' participation in graduate school. National data has demonstrated that African American and Latina/o doctoral students in STEM generally attended less selective undergraduate institutions than their white and Asian peers (NCES, 2003). Mullen, Goyette, and Soares, (2003) found that attending an elite private undergraduate college significantly increases the probability of attending graduate school. Zhang (2005) indicated that graduating from a high-quality college plays a role in determining the quality of the graduate school a student will attend and increases a student's likelihood of enrolling at a major research university. Furthermore, these graduates were more likely to finish their graduate degrees within four to five years.

Using causal modeling, Ethington and Smart (1986) examined the influence of undergraduate involvement on persistence to graduate school and the extent of a student's academic and social integration had a direct and significant affect on their decision to enroll in graduate school. When considering the influence of the undergraduate experience for STEM students specifically, Sax (2001) found that an undergraduate environment that values science increases the likelihood of participating in graduate studies in STEM fields. Sax noted that a genuine commitment to science and higher levels of academic involvement are significant predictors of graduate school enrollment for both men and women. Furthermore, faculty interaction influenced women's likelihood to pursue graduate studies in STEM. Considering that faculty interaction promotes students interest and commitment to science (Pascarella & Terenzini, 1991) and that faculty interaction may encourage URM students to aspire to post-baccalaureate degrees (Carter, 2002), further examination of the undergraduate experience will provide a better understanding of persistence and graduate school interests.

Theoretical Framework

Social and Cultural Capital

There is an ever mounting body of research suggesting that social capital can facilitate desirable educational outcomes and various positive behaviors in students. Increasingly, scholars in college choice literature have been utilizing both social and cultural capital to shed light on the college attendance behavior of URM students (Ceja, 2000; Freeman, 1997; Hurtado, Inkelas, Briggs, & Rhee, 1997; McDonough, Antonio, & Trent, 1997; Perna, 2000). Emerging research has begun to apply these theoretical frameworks to students' social networks across the college years and how these networks influence academic outcomes and post-graduation plans

(e.g. Martin, 2009). Here we examine the role of social and cultural capital as students navigate the intricacies of majoring in STEM and participating in undergraduate research programs.

Bourdieu (1986) and Bourdieu and Passeron (1977) conceptualize cultural capital as resources that are inherited through an individual's social position. Aspects of cultural capital, often inherited through one's family, include attitudes, expectations, and experiences that help define a person's class (McDonough, 1998). Lamont and Lareau,(1988) and Yosso (2001) argue that stratified social systems are maintained through the value placed on knowledge of the "dominant classes" (i.e. upper and middle classes) in a hierarchal society. Stanton-Salazer (1997) defines social capital as relationships with institutional agents that can be converted into socially valued resources and opportunities, wherein institutional agents are "those individuals who have the capacity and commitment to transmit directly, or negotiate the transmission of institutional resources and opportunities" (p. 6). Thus social capital is a form of capital gained and transmitted through social and personal networks which advantages those who are more attuned to the dominate culture (Bourdieu, 1986; Coleman, 1988; Portes, 1998). Therefore, the social and cultural capital of the dominant class is highly valued and rewarded in and perpetuated through educational systems (DiMaggio & Mohr, 1985).

Students utilize social and cultural capital to navigate the educational system (Ceja, 2000; Lin, 1999; Perna, 2000; Stanton-Salazer; 1997); consequently, students who enter college with high-levels of social and cultural capital generally have an advantage over their peers with lower levels of such forms of capital (McDonough, 1998). The college experience can serve as a means for acquiring social and cultural capital, suggesting that academic and social engagement can help to mediate the disadvantages of students who enter college with lower levels of these types of capital (Pascarella, Pierson, Wolniak, & Terenzini, 2004). Thus, while institutional agents can

function as conduits for reproducing race and class social inequalities, they may also function as “lifelines” to resources and opportunities that allow URMs to overcome social structural barriers and experience school success and social mobility (Gonzales, Stoner & Jovel, 2003). We follow Stanton-Salazar’s definition of institutional agents, and Gonzalez, Stoner & Jovel’s usage of the term “agents of social capital,” to refer to “those people who have the capacity and [demonstrate the] commitment to transmit directly, or negotiate the transmission of value resources and opportunities” (p.6) including emotional support, access to privileged information or knowledge, and access to opportunities.

Therefore, a college experience that utilizes institutional agents to provide access to information, opportunities, resources, and networks (Pascarella, et al., 2004) can provide a venue for students to acquire types of cultural capital that are valued, while empowering them by acknowledging and drawing from the types of cultural capital that they bring (Yosso, 2001). Considering the influence of institutional agents in generating social networks that transmit high levels of social capital through mentoring and peer relationships (Stanton-Salazar & Dornbusch, 1995), the opportunities available through structured research programs can acquaint students to scientific norms and might better enable students to access opportunities within institutions of higher education (Hurtado et al., 2008). Social and cultural capital perspectives are useful, not only in assisting researchers to identify the obstacles that students face in navigating educational programs, but in providing a framework for what is valued within education. This allows scholars to conceptualize how these values can be reframed to promote academic success among underrepresented students.

Methodology

There is clearly a need for further studies exploring the ways in which undergraduate research programs are able to assist URMs in overcoming barriers to STEM degree attainment and supporting them in pursuing graduate degrees and STEM careers. Drawing from this need and the theoretical frameworks of social and cultural capital, the following research questions drove our study:

1. What barriers do undergraduate research program participants face in terms of their progress towards completion of an undergraduate degree in science?
2. How do program administrators and programmatic functions help students to overcome these obstacles?

As an interpretive and descriptive qualitative study, we are interested in understanding how participants make meaning of their involvement with undergraduate research programs and our understanding is mediated through ourselves as instruments of the research (Merriam, 2002). As such, we repeatedly reflected upon our own positionality and the impact of our own complex gender, racial, SES, and educational identities on the ways in which we interacted with students and interpreted the resultant data. Additionally, we employed inductive data strategies wherein the data is the foundation of our understanding and the findings are deeply descriptive and conveyed through quotes and thematic analyses.

In this study, we employed in-depth interviews in both individual and group settings. This data collection technique involves a conversation between the interviewer and interviewee that requires both active asking and listening and yields exploratory, descriptive and explanatory data. This method of data collection was used for multiple reasons: its usefulness in a pre-arranged setting, the ease with which it allows the interview process to remain issue oriented and

focused, and its ability to draw out “thick descriptions” of the lived experiences of participants (Hesse-Biber & Leavy, p. 119).

We employed this in-depth interview technique in a collective case-study methodology, wherein we describe multiple cases to provide insight towards answering our research questions (Stake, 1995). This collective case study was defined as a “specific bounded system” that involves the investigation of both institutions as cases and the students and administrators themselves as a case (Stake, 2000).

Site Selection. Ten focus groups and sixteen individual interviews were conducted with students and program administrators involved in undergraduate science research programs on five different campuses across the U.S. The campus sites included two predominantly White institutions (PWIs) and three Minority Serving Institutions (MSIs). Two of the MSIs are located in the Southwest and classified as Hispanic Serving Institutions (HSIs). One campus is classified as a Historically Black College and University (HBCU) and located in the South. Of the PWIs, one is located in the West and one is located in the East.

The sites and participants were purposefully selected, as each of the institutions offered formal undergraduate science research programs and had high rates of science degree completion for URMs, while all of the participants were actively involved in these research programs. We utilized purposeful sampling in order to capture “information-rich cases that elicit an in-depth understanding of a particular phenomenon” (Jones, Torres, & Arminio, 2006, p. 65). The three MSIs had undergraduate research programs that were funded by National Institutes of Health (NIH), including NIH Minority Opportunity in Research (MORE) Programs: Minority Access to Research Careers (MARC) and Minority Biomedical Research Support (MBRS). One institution’s program was funded by the NIH Initiative to Maximize Student Diversity (IMSD).

The two PWIs had various support programs for undergraduate students of color that were funded by other agencies including local initiatives (i.e., Academic Enrichment Programs), National Science Foundation (NSF) sponsored programs (i.e., Alliance for Minority Participation), and private foundations (i.e., Howard Hughes Medical Institute).

Although the undergraduate research programs had similar goals of increasing participation of URMs in research, they were very different in their administration. At one campus, the program was housed under the Office of Minority Education and had a full-time staff coordinator and support from administration. At other campuses, there were multiple undergraduate research programs, some housed under student affairs and some housed within academic departments, which resulted in lack of coordination between programs. Additionally, some programs were housed within academic departments and were directed by full-time faculty with little administrative support.

Interviews. Focus group interviews, ranging from 45 to 90 minutes, were conducted with 2 to 12 participants per session. Each focus group session was conducted by at least two researchers, with one facilitating the discussion while the other took notes. The 70 student participants represented a diverse group: 56% Latina/o, 18% Black, 13% Asian American, 8% multiracial, 2.5% American Indian, and 2.5% White. Women constituted 60% of the sample, and the majority of students (70%) were biology, biochemistry, or chemistry majors. We also conducted 45- to 90-minute individual interviews with faculty members or administrators affiliated with the undergraduate research program on campus. The sample primarily consisted of coordinators, assistant directors, and directors of science research programs, but also included science faculty and upper-level campus administrators. For both sets of interviews we employed a semi-structured protocol, which addressed the following broad thematic categories: types of

support offered by the program, program evaluation, students' interest in science, educational and careers goals, undergraduate research experience, and obstacles facing URM students.

Analysis. We recorded and transcribed all interviews verbatim, then loaded each document in NVivo 2 software wherein we began the process of open coding by examining the raw data and coding for salient categories supported by the text. Creswell (1998) describes this process: “using the constant comparative approach, the researcher attempts to ‘saturate’ the categories—to look for instances that represent the category and to continue looking and interviewing until the new information does not provide further insight into the category” (pp. 150-151). These “categories” or themes in the raw data, were then labeled as “nodes.” Using NVivo, the raw data were coded by selecting relevant sentences representing emergent themes, and dragging and dropping these selections into the free node section of the program. The data selected were stored there under the coded phrase and the link to the full record was maintained. Frequencies of occurrence were then calculated for each theme and the most common themes were reported.

According to Jones, Torres, and Arminio (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). Three to four researchers thematically coded randomly-selected sections of text and reliability results were calculated by dividing the number of coded passages by the total number of passages in the selection. The researchers consistently reached acceptable inter-coder agreement levels between 75 and 85 percent (Miles & Huberman, 1994). As a final step, in order to expand upon prior coding efforts utilizing newer software, the data was re-coded utilizing NVivo 8. Thus coding was re-validated and we were able to add new

codes and sub-codes where necessary. Again, researches consistently reached inter-coder reliability agreement levels of approximately 90%.

Limitations

Before we present our findings, we must first discuss one important study limitation. All of the student participants were involved in undergraduate research programs. We did not interview URM STEM students who were not program participants. Our intention in this study was not to conduct program evaluations. Rather, we are interested in a better understanding of the experiences of undergraduate research program participants and how these programs provided support and opportunities beyond the standard curriculum.

Findings

In order to effectively convey the depth and breadth of our findings, we divide and describe the major functions of these research programs into three main parts: (1) the ways in which they provide research experience and exposure, (2) the access they offer to supplemental services, and (3) the ways in which they supply students with sources of personal support. As we describe each of these major programmatic functions, we also examine the barriers and obstacles that they serve to mitigate.

Provide Research Experience and Exposure

For students in the early stages of their academic careers, finding direction is often a challenge. The students participating in undergraduate research programs struggle not only to navigate college itself, but to understand the intricacies and possibilities of a potential career in science. As such, a major function of these programs is to introduce students to what science is, where it can take them, and what the possibilities are for both graduate studies and scientific

careers. Below, one administrator from a PWI described the need to provide students with this knowledge:

You know, when you talk to people about engineering and they're from a first-generation family, they don't understand how many types of engineering there are... there's structural engineering, there's bioengineering, there's mechanical engineering, there's computer science and engineering, and lots of different kinds of...same things with the students who want to go into the health profession, a lot of them, particularly again those from non-academic backgrounds, think that means being a doctor but there [are] a lot of people who don't know all the things that you can do.

Almost all of the administrators described similar situations with students entering their programs. Informing students not only about the possibilities for participation in these programs, but also about their options for graduate school were obviously essential elements, as two administrators described:

Nine out of ten of them have never heard of the program, so that let me know that they just don't know about it, so that's been a big part of my focus, which is to increase participation. (Female administrator, PWI)

I think for students of color, it's oftentimes a challenge just getting through undergraduate school, they haven't even contemplated graduate school and the fact that they possibly could work with a research institution, whether it be a pharmaceutical company or an academic institution. You've got to have people inside talking to them about the possibilities. (Female administrator, PWI)

As several of the administrators noted, many students think science can only lead to one career path, being a medical doctor. They know what a doctor is, and what a doctor does, while the career of a research scientist remains mysterious and nebulous. This was the case for many students we interviewed, as many of them lacked understanding and exposure to STEM careers. Despite their initial interests in medicine, once they began participating in these research programs, some of them gained a new knowledge of research and found it to be a better fit for them than medicine:

I actually applied to the program wanting to know, 'Should I go into medical school or graduate school?' Once I was in the program and I started taking classes and stuff, 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. If I wasn't in the program, I really wouldn't have known that. I mean, I never really knew this side of a science degree existed until I was kind of brought into the program...the only research or the only thing that I knew was a doctor, the medical side. You never really see the other side of it. (Male student, HSI)

Having people talk to students about the possibilities of research and allowing them to experience it themselves pays off, as so many students clearly expressed how their participation in these undergraduate research programs had both piqued and cemented their interest in science. One young lady echoed the student's sentiments above as she described how the exposure to research opened her mind to the idea of science as a career:

I think with my experience...the program really helped me, because I hadn't really thought about it before, but after my first year, I thought it was really something I could get used to and really like it. (Female student, PWI)

In this same vein, both administrators and students described the importance of not only exposure to what science is, but building real life, daily experiences in research. One administrator states:

So they learn great interpersonal communication skills, gain confidence, get a grip of what real research is like, the good, the bad, and the ugly. (Female administrator, PWI)

This idea of “getting a grip” on what real research is was a critical element for students. As students began the process of exploring science as a career, the hands-on nature of experimentation became important to them, as did the ability to ask and answer questions. They found great value in being an active researcher, learning how to be a scientist, and publishing their findings, all of which were made possible by their participation in these undergraduate research programs. Here students described how vital this hands-on research experience was to their learning process as budding scientists:

You know, it's providing us with this other way of looking at these sciences and, I think for me, that's one of the biggest things, the biggest way this research...or this program is supporting my career goals, just like teaching me how to be a scientist and showing me the research to give me an active interest in biology. (Male student, HSI)

Early on as an undergraduate in biology, you hear about all these studies that other people have done, but when 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. (Male student, HSI)

Indeed, students who were interviewed credited their participation in research programs as a major reason for continuing in their respective STEM major. As one male student from an HSI stated, "Working in the lab pretty much the last year has been the only reason I've stayed in biology." Through this in-depth exposure, students were socialized into scientific processes and environments.

Inherent in participation in these research programs, participants were taking on both the role of a student and a researcher. As a result, many students expressed difficulty in balancing their research and their course work:

I think trying to juggle doing research and getting decent grades is hard sometimes because you have to prioritize like, 'OK, I have a test, so I need to either take some time off'...and you can't always do that if you're in the middle of a project, so it's hard to decide what's most important at that point. (Female student, HSI)

If anything, that transition is the hardest...learning how to balance research and classes, because research is different than some job like at the mall or something. You have to keep your brain engaged the whole time. There's no turnoff time from going to a class to your lab, so it's hard to figure out. (Male student, HSI)

Indeed for many students finding this balance was difficult, and succeeding as an undergraduate STEM major was fraught with many unique challenges. As such, each research program offered a host of supplemental services in an attempt to help students navigate the complex path towards a STEM degree.

Access to Supplemental Services

While the provision of academic support and research experience is the stated purpose of undergraduate research programs, most administrators felt compelled to expand services beyond the intended scope of the program in order to counteract the barriers many students faced as they pursued STEM degrees and participated in research. These programs provided a host of supplemental services to students including: Graduate Record Exam (GRE) preparation, guest speakers, and seminars on a broad range of topics including STEM career paths, scientific writing, and presentation skills. They also encouraged and financially supported students in attending conferences, all while providing them with monthly stipends. Both students and faculty alike insisted that the supplemental services provided by these undergraduate research programs were important factors in combating barriers. One female administrator from an HSI listed the specifics of her program's support services as:

Basically, [these programs] are geared towards getting more under-represented minorities involved in a career in research and the way we do it here is by developing them...by them taking classes through us, by them attending seminars, by us funding them to go on to scientific conferences every year, offering GRE preparation, and encouraging them to take upper level classes, and then as well as giving them financial support.

The host of services provided by these programs did not go unnoticed by students. They were keenly aware of the opportunities available to them that went above and beyond those afforded to the average student.

As mentioned previously, students were also provided with opportunities to attend conferences and make presentations in various settings. Many of the administrators stressed what an important element this was to students' development as scientists. Each program had specific trainings to help students improve their presentation skills and actively encouraged students to attend conferences, as this female administrator from a PWI described:

We also take students to conferences to present and that's very important too. We have a symposium, which is once a year where students from all our campuses present and they really enjoy that. It's over one week and we also tell them, 'If there's a conference that you want to go to, let us know and we'll see if we can help you pay for stuff.'

The importance of this activity was not lost on students, many of whom described conference attendance as premiere learning opportunities, both personally and professionally. For them, conferences were places to network with other people like them, and to share their hard work. One student from an HBCU described how encouraging it was for him to see other people his age working on similar projects:

[The program] just really helped me to focus on actually doing research and just even get me interested in going to conferences, presenting the research that I'm doing, and also just really getting interested in other people's research, and so for me, I guess having the opportunity to go out and see that there's other people that are even my age doing the same is a real big encouragement to me, and so... that's probably been one of the biggest things.

Not only did these programs give students financial support when they attended conferences, but they supplied students with a monthly stipend. For most of the students interviewed, this stipend enabled them to conduct their research without financial concerns. Otherwise, they would have to work elsewhere in order to support themselves and their education. This was well understood by all of the administrators, who recognized it as a top priority:

I think money is a really big ...a lot of our students need to work and that can affect their performance. It can also affect their ability to participate in our summer program and we have a stipend, but sometimes if they make more money than they get from our stipend it's hard for them to turn it down. (Male administrator, PWI)

I think the financial situation of the students would be one thing that might impede them because...well, if I put [it] in a different way, some of them, they have to work in order to go to school, and so if they were to just volunteer in a lab, they probably wouldn't get to that point of saying, 'Yeah, I think I could do this,' because they wouldn't be able to spend enough time there or they wouldn't get the same project going, and so I think with us paying them to work in a lab, that helps them. (Female administrator, PWI)

While students deeply valued their research experiences, the necessity of working trumped their desire to continue in their labs. Many students stated outright that if they were not getting paid for their work in the lab, they would have been unable to continue. This was an element of the programs that truly met students' practical needs and enabled them in a very concrete way to explore scientific careers. They described the importance of this financial support clearly:

And to be honest, a program like this where you get paid and you get to do research is great because...it's like you really need the experience to go to grad school or you need experience to get a job after college, but if you don't get paid ...and you don't have anyone to support you financially 100 percent, then you struggle and you have to choose between waiting tables, which will do nothing for you after college, or getting some real experience. So programs like these are really good because I've known people who work in labs and don't get paid and are volunteering, it's like I could have never done that. (Female student, HSI)

Well, when I first started doing my research, I was doing it for free and at that time I was working and after about a week or two, I was like I can't handle doing research, working, and going to school, so I had to quit my job and I was kind of trying to figure out what I was going to do and my PI told me about this program, so that was kind of a lifesaver, being able to get into that and get paid for what I [was] doing already. (Male student, HSI)

Sources of Personal Support

Beyond preparing students for scientific careers through exposure to research and supplying them with all of the aforementioned services, these programs also played a critical role in expanding students' social networks through linkages to faculty mentors, peer support groups, and professional connections. These networks not only provided professional and academic advising, but also served as sources of personal support and encouragement and helped to build a sense of community.

The aforementioned were particularly beneficial for students from underrepresented backgrounds due to the fact that aside from the unique stresses associated with being STEM

students, they also faced a host of other challenges particular to their URM status, one of which was racial isolation. For students, it was challenging enough not to see many other students of color who could share in their unique experiences but they often found themselves as “the only one”:

I'm involved with the minority community, but before that there was nobody that was really going through the same things that I was, like I was in a class before or one class before that like...honestly, I can count the number of members of the minority community on one hand and how many people are actually applying this year, I have nobody to really look up to. (Female student, PWI)

Well, in my major, physics, you can count the number of Black people on one hand and that's over two years and there are only two Black females, and me included...and then being in a department where there are no minority professors...a lot of times I feel very alienated. (Female student, PWI)

This lack of racial minority presence obviously extended beyond the student body and into the faculty. Many of the administrators described their acute awareness of the limited number of faculty of color:

I think I mentioned the lack of role-models. I don't think there are any African American faculty in the School of Engineering and there aren't that many in any field. There aren't that many Latino faculty in the sciences, so I think the lack of role-models is a really big issue. (Male administrator, PWI)

But I just try to kind of build a little sense of community on this campus with the few African American staff members, faculty...and we won't even get into the dismal faculty figures...just horrid. The only way I can describe it is horrid...and that's part of the problem too, you see, when you don't see yourself represented. (Female administrator, PWI)

This problem was exacerbated by the fact that interactions with any and all faculty members were typically rare and only on relatively superficial basis. Here two students at an HSI described this challenge:

You take the biology, and you go into the class, and there's hundreds of students there.

They're not all going to get their questions answered by the professor. If you're lucky, you might get the TA to answer it. (Female student, HSI)

I think it's just really hard for us because we don't know the professor that well in a class of 400 students and you...like you can go to office hours every week and...very few take the initiative to learn your name, that's number one, and so you don't feel like they know you. (Male student, HSI)

These programs enabled students to get to know faculty members by providing students with more frequent opportunities to interact with faculty through organized sessions. These interactions were typically on a smaller scale and enabled students to get personal attention from the faculty member. Here one administrator described such an activity:

Well, I think that we probably don't call them community building, but there is...coffee with faculty...even though this is a fairly large program...I think there are more 200 students registered in it now...but coffee with faculty might be 10 or 12 students who just have coffee with a professor. (Male administrator, PWI)

Students realized that these opportunities to spend significant time with faculty helped them a great deal, that through these smaller scale interactions faculty got to know them and were more willing to provide letters of recommendation, advise them regarding graduate school, and help them make further connections. Students greatly appreciated these opportunities and felt they gained a significant amount from them, as two students described:

I think it also gives you a good ability to network with a lot of the faculty, professors, and researchers that you might not otherwise have talked to and get recommendation letters and you also get like their help with what they know about grad school. (Female student, HSI)

Another professor that I worked with, she was also very helpful and helped me with my CV and she called one of the schools that I was applying to because she was friends with some of the other professors there. (Male student, PWI)

Beyond providing specific venues for interaction with faculty members, research programs often functioned to match students with a lab, which included a faculty principle investigator and a team of researchers consisting of graduate students and post-doctoral fellows.

These labs provided numerous sources for mentorship and academic and personal encouragement, as the following two students described:

My PI is extremely supportive, and I hope other people's PIs are as great as mine, and I guess it's great that they found individuals or PIs to participate in the program that have...I don't know, they have dreams for us and their students, and they want us to do really well because people in my lab, not just my PI, but people around, they are very supportive, and if they know you're going to a conference, everyone gets riled up and excited and they want to hear about it, and they send you emails saying, 'Congratulations,' and I think that's a great support line. (Female student, HSI)

That means the PI is going to get you to publish. They are on your case about it and they show you exactly how to do it. They outline it, they walk you through it, they help you get used to all the different journal formats, and once you do that, you're done...you've kind of hit the most important thing you need to be able to do. (Female student, HBCU)

The students above described how critical it was to receive the emotional support and encouragement in addition to the more tangible forms of academic support. They also described the sense of community the programs created by linking students to multiple sources of faculty and peer encouragement. One administrator described how her program takes the approach of surrounding students with a supportive community:

I think it's successful because of the community aspect, a place where those that are in the program feel that they belong to something special and that there's somebody out there that cares. The students feel that they have some sort of accountability that's more than just to themselves, that somebody's out there thinking, 'Hey, I'm here caring about your success, so you should care about your success as well,' and I think that's what makes a successful program. (Female administrator, PWI)

Both students and faculty alike insisted that personal and emotional support mechanisms were equally, if not more critical to students' success than the academic support provided by undergraduate research programs. The supportive spaces and the treatment of students as whole people often stemmed from the tone set by individuals leading the programs. The individual efforts of program directors were essential elements of programmatic success, as they themselves

made students feel that they were always there for students to turn to and to lean on for support.

Here some of these individuals reflected upon their own efforts:

You have to nurture them...as coordinator of this program, I do lots of nurturing, hand-holding, I have to do it. I am really proud of the fact.(Female administrator, PWI)

We do follow their career goals. We talk to them. They do an exit interview with me and it's a personal interview and I'll do that at the beginning of their senior year. I talk to them about their experience in the program, how we can improve the program, what their plans are, are they doing things right? Have they applied to graduate school? Have they taken their GRE? Check on this stuff like that with them, but rather than doing that on the phone, we talk. (Female administrator, HBCU)

A great number of students recognized the essential role that the program administrators played and described many of the formal and informal interactions they had. Students acknowledged all of the help they had gotten from program administrators with gratitude and praise, as this young lady from an HBCU described:

She's the greatest. She's constantly bombarding us with emails about different graduate programs and she brings in different people, like this one woman she brought in who can help us with our personal statements and things of that nature. So she brings in people that help us out, but she's just a cool person in general. I really like the director and assistant director too. They're constantly, constantly giving us advice about graduate school, what it's like, what you need to do to get in. They'll read your essays, they'll help you with your applications. You could always go in and talk to them about classes or what to do when you have a disagreement with your teacher and things of that nature.

Aside from receiving support from faculty and administrators, students also described a great deal of support as coming from their fellow program participants. They enjoyed being surrounded by like-minded peers who shared their common experiences, and felt truly appreciated and understood:

I think that's another reason why the program is really great, because it surrounds you with people that are kind of your age, you have the same interests. They appreciate your work I guess and they can appreciate when you say, 'I can't believe what I did today in lab.'(Female student, HSI)

Other students expressed how being around other program participants inspired them and sparked their interests:

Just being around people like you guys, to me that's inspiring because I see so much drive, so much focus, so that to me...like it makes me want to do it more, it makes me want to be more interested in everything, so even though, yeah, we have our university peers and everything, within the program just everybody's so dedicated to their research and to science in general that you just kind of feed off of it. (Male student, HSI)

The administrators too saw the impact that this student networking had on student success. One female administrator from an HSI described how students seeing one another succeed gave them confidence in themselves:

I think seeing other students do it...you know, the interaction of the peers and of them being able to see that, 'So-and-so can do it and she's graduating, I can do it too, and she just got in...or she just got accepted and I have a pretty good chance too. If she can do it, I can do it.' I think that makes a big deal.

In addition to peer networks, programs also considered the ways in which students' families could be incorporated into social networks in college, since for many students their families were clearly a source of strength:

Well, it's been support from both internal, like they said, and externally, like family from members and friends, and even...it's funny, regardless of the relationship you might have with all the family members in your family, they're all pushing you...you know what I'm saying...for the same goal, to graduate and move on to doing better things, so that's a good thing. (Male student, HBCU)

Yet as discussed previously, many students entered college with little understanding of what a career in science research would entail. Through their involvement in structured research programs, students' knowledge in this area progressed; however, their families' knowledge did not necessarily grow accordingly. Students expressed that this conflict between their STEM studies and their families most commonly came from family members lacking familiarity with the value of STEM degrees and research oriented studies and the emphasis they placed on

earning money as soon as possible. Here two students discussed their families' responses to their pursuit of STEM degrees:

I mean, my family...they're working and they're earning a paycheck and I'm not, so it kind of looks like, 'Well, what are you doing and then what are you going to do after you graduate?' 'Oh, just keep going to school.' It's like they don't understand that I want to do science. I think now, my parents are starting to understand and my family...but like I said, when you look at other people in my community...they get a job and that's what you're expected to do, ...you know, we've already been working before or we're older and stuff and you have family, you have kids, it's kind of expected...you know, you need to fall into your role. (Male student, HSI)

My family doesn't understand what a chemistry degree does and a good chunk of everyone else I know doesn't understand what I'm going to do with my life, so that's a big problem I'm facing. I understand what I want to do, but they're like, 'Why do you want to do that? You could have been a doctor or something,' but that's not my cup of tea. (Male student, HBCU)

In such cases, undergraduate research programs developed services to reach out to families to clear up these misconceptions of graduate school and scientific careers and to get families more involved with students' STEM education. For instance, one female program director from a PWI described her outreach efforts:

In the newsletter, every quarter I try to talk about the students who are doing research, the students who are graduating, and an article about this and that, and I tell students 'If there's anybody you want me to send this newsletter to, your parents or a friend or family, let me know,' and I have students, 'Yeah, please send it to my parents! Here is the address.' It's just a little something to maybe get their family more involved.

Administrators evidently recognized that the success of structured research programs was heavily reliant on their sensitivity to the familial networks that students belonged to prior to entering college.

We have discussed the many challenges that URM STEM students face: alienation and racial isolation, conflict between their families and their STEM pursuits, monetary issues, finding balance between their research and class work, and gaining awareness of and exposure to

research. In describing the many aspects of the findings of this study, we have addressed the ways in which program administrators and programmatic function help students to overcome these obstacles and barriers. By providing research experience and academic support, access to supplemental services, and sources of personal support, these programs are able to mitigate many factors that contribute to the high attrition rates amongst URM students in STEM majors.

Discussion

The barriers to persistence for URM students in STEM include financial concerns, racial isolation, academic intimidation, misconceptions of graduate school and scientific careers, and mismatch between personal goals and goals inspired by family. These barriers have been documented in previous literature and are highlighted in this study.

Structured research programs have been widely credited with supporting students to overcome barriers to persistence in STEM (Barlow & Villarejo, 2004; Chang et al., 2008; Perna et al., 2009). While the findings of this study affirm the positive benefits of URM undergraduates' participation in structured research programs, we expand the previous research by identifying specific support mechanisms and examining the scope of these programs. Prior research has examined the factors that contribute to college degree completion, but few researchers have studied the experiences that increase the chances of pursuing graduate school. Previous studies have also focused on a single program or institution, while this study sought to identify unifying characteristics across different programs and institutional contexts. In addition, the qualitative constant comparative approach, adopted in this study, provided deep insights into how undergraduate research programs support students in overcoming barriers to persistence in science.

Equal percentages of URM and White students enter college intending to pursue STEM

majors (College Board, 2005); therefore, the low retention of URM students in STEM does not point to a lack of motivation or interest on the part of students, but rather it indicates there may be challenges associated with access to resources. Information, opportunities, and access to faculty and peer social networks in STEM are all forms of social capital necessary to navigate the complex path towards college degree completion and the pursuit of graduate studies in STEM fields. Prior to entering structured research programs, URM students often envision the career path for STEM majors as constrained only to healthcare professionals and clinicians. Specific forms of support offered by structured research programs demystified these preconceived notions to provide a clearer understanding of careers in STEM. For instance, through exposure to lab environments, grant writing, and the publication process, students were socialized into scientific environments and practices.

On the surface, the primary function of these structured research programs was simply to provide students with research experience and exposure to lab environments. But this single approach could not ensure that a significant number of URM students would pursue graduate school and careers in STEM fields, so these programs administrators adapted to students' needs and offered much more. Beyond their stated mission and purpose, structured programs also provided mentoring, academic support, social support networks, Graduate Record Exam (GRE) preparation, and a variety of seminars on scientific writing, presentation skills, and STEM career paths. The multitude of services required to support URM students in STEM cannot be attributed to students' failure to take advantage of available resources as evident in their determination to seek out and remain in structured research programs, despite the rigorous demands in terms of time and personal commitment. Access to privileged information, resources, and social networks were

among the forms of social capital needed to complement the motivation and initiative students' already possessed.

The second major function of these structured programs is to offer basic support services; however, many have expanded their services beyond their intended scope, often to attend to very basic, unmet needs of students. For students who had to simultaneously balance school and work in order to support themselves, without funding, many of them would have been unable to voluntarily participate in the lab nor would they even consider applying to graduate school. As indicated in the findings, the financial support provided by structured research programs proved to be the difference between being "a waitress or a scientist." The various forms of academic enrichment provided by structured research programs gave students the fundamental skills and tools needed to successfully navigate the educational system.

The third and arguably most vital function of structured programs was to expand students' social networks through linkages to faculty mentors, peer support groups, and professional associations. The goal of these formal and informal social networks was to bridge differences such as race and socioeconomic class by cultivating relationships between students and groups of people with similar interests in scientific work. From a social capital perspective, these networks provided URMs with access to information and campus resources traditionally available only to communities with higher levels of social capital. For instance, programs sent students to professional conferences not only to acquire knowledge and improve their presentation skills, but also to give them valuable opportunities to meet people, make contacts, and exchange ideas with other likeminded scholars and scientists.

Additionally, students commonly emphasized the importance of maintaining informal personal relationships with peers and faculty. While these relationships also granted students

access to privileged information and opportunities, the main purpose was to provide social capital through the transmission of emotional support. Having support and encouragement from peers in the major was crucial to students who often felt external constituents, such as friends and family, lacked an intimate understanding of the personal adversity they experienced in pursuit of a science degree. Faculty administrators overwhelmingly mentioned the critical need to nurture not only the academic but also the personal side of students, and students often relied heavily on these administrators to provide guidance on how to balance school, work and personal commitments.

Implications

The findings of this study help to confirm the importance of structured undergraduate research programs in supporting URM STEM students to persist through their undergraduate majors and into future careers as scientists. The structured undergraduate research programs helped the student participants increase their social capital in key areas related to future careers in STEM. Unlike students from elite backgrounds who begin their undergraduate experiences with understand and have the resources needed to navigate the respective higher education institutions and STEM fields, the student participants were able to increase their social capital in these key areas through access to social, peer, and academic networks. As a result, students were better able to articulate what a STEM career entailed and pursuing graduate studies in STEM became a more viable pathway.

Several program administrators indicated there was a lack of institutional support and funding for these research programs. Some programs had unstable and diverse funding sources leading to tumultuous financial decisions regarding programmatic functions and staffing. Clearly, these undergraduate research programs can have a substantial impact on the persistence

rates of URM STEM undergraduates and may also increase the proportion of students who pursue graduate studies and careers in scientific research. However, due to limited and often unstable financial resources relatively few underrepresented racial minorities are afforded the opportunity to participate. Moreover, a sustained effort will garner significant change, as a program that was started with soft grant monies can only temporarily make a difference at the respective institution. University administrators and stakeholders must strongly reevaluate their commitment to producing a racially diverse STEM citizenry and workforce. The rhetoric of mission statements and public relations campaigns are important for fostering a welcoming environment and a sense of inclusiveness, but there is nothing that compares to demonstrating commitment through action. Therefore, universities must seek to institutionalize and expand these structured undergraduate research programs to meet the needs of highly interested African Americans, Latinos, and Native Americans in STEM.

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