Near-Peer STEM mentoring displays synergistic benefits for underrepresented minority mentoring

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**Abstract** (50 words):

Undergraduate research experiences can launch science careers, but are not universally accessible and poor experiences can cause an early exit from science. We established near-peer mentoring programs for underrepresented students to address these limitations. Access to undergraduate research improved for mentees, but mentors also accrued benefits, amplifying the program’s impact.

Key words: Near-peer mentoring, underrepresented students, STEM, sense of belonging, self-efficacy, science identity

**INTRODUCTION**

Research experiences improve academic performance and sustain interest in research careers for all undergraduates (Fechheimer et al., 2011; Russell et al., 2007). However, for underrepresented minority (URM) students, mentors may play an equally critical role in supporting their advancement in science, technology, engineering and math (STEM) research careers. For example, studies have shown that inadequate mentoring can adversely affect performance in research opportunities and cause URM students to leave careers in STEM fields (Johnson, 2007). Furthermore, the inability of most colleges and universities to provide research experiences to all undergraduates results in unequal access to this valuable activity. Inadequate mentorship of URM students engaged in undergraduate research limits the ability of this evidence-based approach to increase the diversity of the scientific workforce.

Effective research mentoring has been shown to enhance recruitment and retention of URM students in STEM, and increases persistence towards research careers (Hathaway, et al., 2002; Gregerman, et al., 1998). Underrepresented students who are mentored display higher retention rates (Alberta et al., 2001) with effective mentoring reported as a key factor in completing an advanced degree (Solarzano, 1993). In fact, several studies of minority and non-minority medical faculty find that the quality of mentoring is linked to increased publication rates, job satisfaction, and career advancement (Schapira et al.,1992; Palepu et al., 1996; Steiner, et al., 2002; Wingard et al., 2004). For underrepresented minority faculty with mentors studies find that they are more confident, and feel better supported in their work and career advancement (Beech et al., 2013).

While benefits to mentees engaged in mentored research experiences are clear, benefits to mentors have not been well documented. For example, while it has been shown that increased productivity among undergraduate research mentees inevitably leads to increased productivity for mentors (Dolan and Johnson, 2009), other benefits are not well studied and are largely anecdotal. Other benefits to mentors described in this way can include personal satisfaction and enhancement of management and leadership skills for professional development. Additionally, effective mentors facilitate the recruitment of savvy and dedicated students to the mentor's research program. These benefits can be accrued by senior mentors who lead research programs regardless of minority status, and in this report we examine benefits accrued by near-peer mentors from historically underrepresented groups in science at a minority-serving institution.

Near-peer relationships are characterized by the pairing of individuals who are slightly more advanced in learning and/or training with individuals who are less advanced, and we find that this pairing accrued unexpected benefits to the slightly more advanced mentors. In particular, we find that near-peer mentors from underrepresented groups voice changes in attitudes and perceptions linked to increased persistence in science. Thus our near-peer mentoring approach appears to not only benefits mentees by overcoming some of the limitations imposed by the lack of universally accessible and sometimes poor research experiences, it also benefit mentors. In this way our near-peer mentoring approaches amplify efforts to increase diversity in STEM.

***Approach*: Informal and Formal Near-peer Mentoring**

There has been an increase in the numbers of URM students entering STEM degrees and involved in undergraduate research, however this has not translated into increased numbers of URM professionals in STEM careers. Several studies suggest that students involved in undergraduate research can act as a pathway for careers in STEM (Lopatto 2007, Russell et al., 2007, Thiry et al., 2011). However, retention of URM students in STEM majors and access to research opportunities persist as a major barrier towards completion of degree programs. Here we propose that near-peer mentoring strategies will increase retention rates in STEM majors and provide knowledge and access to research experiences. We employed both an informal and formal near-peer mentoring strategies to increase exposure to scholarship and undergraduate research opportunities, reduce social isolation, build a support network, and increase self-efficacy.

*Informal near-peer mentoring program: Biology Undergraduate Mentor Program (BUMP)*

In order to address the aforementioned issues, we implemented an informal near-peer mentoring strategy with lower-division students being mentored by upper division undergraduate students within the Biology department at San Francisco State University (SF State). Near-peer mentoring has been used by many universities and educational non-profit organizations and has recently been the focus of a national effort to increase U.S. graduation rates through STEM mentoring to become the highest in the world by 2020 (Nekuda Malik 2014). In addition, near-peer mentoring has been shown to be extremely successful in the STEM research environment (Tenenbaum et al., 2014). Here, we created the Biology Undergraduate Mentor Program (BUMP), a pilot program that lasted for a year (Fall 2012-13) with four upper-division undergraduate mentors and 16 lower division undergraduate biology majors. This pilot program used an informal approach where mentor/mentee pairs would meet weekly outside of the classroom setting and discuss topics ranging from best study practices to available resources within the department and university. BUMP Mentees were selected from the introductory Biology course sequence through an application process, which focused on their first exam score and attendance in the course. The introductory biology course is a large lecture style course with over 275 students enrolled and was selected for the BUMP program because this course has been identified by students who have left the biology major as one of the difficult courses to navigate and ultimately led to a change in career. Ideal candidates for BUMP were students who did not perform well on the first exam, but had excellent attendance in the lecture and laboratory sections. BUMP mentors were recruited based on their performance in the introductory course and through recommendation from the instructor. Ideal mentors were not just students who received a top grade in the course, but rather students who showed the greatest improvement in their performance. In addition, there was no requirement for the mentors to be involved in any research programs or internships, however mentors received weekly training ranging from introduction of campus and department resources, communication and study skills, and issues surrounding equity and diversity. It is important to note that all mentors in BUMP identified as belonging to a historically underrepresented group in STEM.

*Formal classroom approach: Research Skills Course*

A near-peer mentoring approach was implemented in a classroom setting in the fall semesters of 2012-2014. This approach was used to better attain the learning objective of mentor young scientist in the practice of science in a paired “Research Skills” course for upper division undergraduate and masters level students. Undergraduates enrolled in the course were matched with master’s level graduate students (2-3 undergraduates per masters student), to engage in a series of workshops to demystify and provide skills for the practice of biological research. The workshops were systematically organized to align with the typical skills needed for engaging in a new research project. Specifically, the near-peer mentoring groups worked collaboratively to conduct a literature search, design an experiment, hone recordkeeping skills, deliver a journal club presentation, and write a research brief. The focus of these assignments was driven by the topic of the graduate student’s research. Thus, in the mentoring groups the graduate students were the more advanced incumbent scientist (mentor), and the undergraduates the more junior investigators (mentee), thereby creating a near-peer mentoring relationship. To promote success of this relationship, the graduate students additionally participated in workshops on effective mentoring practices, and were encouraged to work together to find their own examples of effective mentors. In fact, one of the learning objectives for the graduate students was to “*gain skills to mentor young scientists in the practice of science*.” Taken together, this objective was achieved via mentoring workshops for the graduate students, and hands-on experiences in mentoring the undergraduates. Given the novelty of this classroom approach, it was important to assess its efficacy. Thus, mentors were assigned journaling activities (i.e., mentor reflections) to gather evidence regarding the efficacy of the pedagogical approach.

***Evaluating Approach:* Collecting and Analyzing Student Voices**

To track changes that occurred over the course of the research skills course and the mentoring program, a variety of qualitative assessments were collected. In addition to data from BUMP mentees collected during the semester they participated in the program, BUMP mentors were asked to complete a reflection at the end of the semester in response to a prompt (*Question*: In what ways has BUMP impacted your professional life thus far?). Mentors of the research skills course were asked to complete reflective journals throughout the course of the semester to periodically assess progress and group dynamics.

In both informal and formal mentoring programs, reflections (including reflective journals) were read at least once before initial analysis. With second or subsequent readings, quotes were highlighted and labeled for particular themes. Reflections were read again without highlighted text to ensure that additional themes or quotes were not omitted. Themes were then clustered into similar groups, depending on relevance. For example, themes from research skills course mentors, particularly early in the course, included initial feelings of reluctance and inadequacy. Among the themes identified were sense of belonging, self-efficacy, and science identity, which are explained in more detail below. Individual quotes representative of themes were then read for completeness and to ensure context was conveyed correctly. If an individual quote on its own did not appear to convey the theme correctly, the quote was selected from its original context and additional sentences that represented the theme were included. Quotes not used in the text are included in supplemental material (Appendix A)

**Boosting Sense of Belonging**

Negative perceptions of a STEM environment as a place where particular students “do not belong” can lead to poor academic performance and exit from science (Good, et al., 2012; Purdie-Vaughns et al., 2008; Schmader, et. al., 2008). This is the environment typically faced by students who are historically underrepresented and enrolled in science classes, and it can diminish their perception of the value of STEM (Aronson, et al. 2002; Osborne, 1995; Steele, 1997). In addition, a lack of role models can be a defining factor in generating an imposter syndrome phenomenon in students directly affecting their sense of belonging within STEM majors (Clance and Imes, 1978; Jackson and Heath, 2014,). These outcomes are a result of environmental cues that fail to signal safety and valuation of diversity (Murphy, et al., 2007; Walton and Cohen, 2011). The exit of URM students from STEM at the expense of the student’s well-being, as well as that of diversity of thought and practice of research within the scientific field. It is common to believe that these factors affect only mentees within the programs, however our findings suggest that many mentors also experience a lack of belonging within their majors and scientific community. Our near-peer mentoring approaches address these environmental cues and boost sense of belonging not only of our mentees in the programs but the mentors as well, as demonstrated by the voices of the mentors. One mentor in particular stated, “*Being one of the first mentors, I think I am helping to shape the program and determine its future goals. That in itself has impacted me greatly, as I feel that I am a part of a community at San Francisco State University*.”

**Bolstering Science Identity**

Identity can be viewed in two ways, either as a social construct (i.e. group affiliation), or as a personal view of self (Fearon, 1999). When we explore our identity in STEM, we look to our community for affirmation as a scientist and our own personal perception of what defines a scientist. This concept of ones “scientific identity” can be a critical factor in persistence and successful outcomes in research and training towards STEM careers (Carlone and Johnson, 2007). A recent study provides the framework to characterize science identity into three components: recognition, competence, and performance (Trujillo and Tanner, 2014). In reflection essays of the mentors involved in BUMP and the Research Skills course, we found that through mentoring, the mentors showed strong improvement in each of theses categories. Reflection from a mentor in the research skills course showed an increase in competence, “*In fact, when I realized on the first day of class that I would be a mentor I was scared and apprehensive; I had little confidence in my ability to present information about the scientific research field in a constructive and helpful manner. However, I came to realize over the course of the class that I have actually had more experience in the research field than I have cared to give myself credit for. Even if I feel like an inexperienced and sometimes overwhelmed researcher, I still have a lot offer as a mentor to aspiring scientists like the undergraduates in this class. For instance, many of the undergraduates have not been a part of a lab and the fact that I have actually been a part of a lab and conducted both successful and unsuccessful experiments means that I can give them an introduction to what the day-to-day experience of conducting research is like. I also realized that having been to graduate school interviews and going through the application process to get into the master’s program at SFSU are more unique experiences than I had initially considered them to be. There is a lot I am able to help others with in terms of informing them of what to expect and what can make them more successful in preparing for taking the next steps after obtaining an undergraduate degree.*”

Another mentor reflection displayed increased recognition of science identity through mentorship for success at the next level of their education goals, “*Now that I am applying to PhD programs this fall, I feel l have an edge over other applicants because of the skills I have learned from the BUMP program. My mentorship abilities have tightened and reinforced how I present myself professionally, and in addition I know I have real world experience that applies directly to academia. I know that typically when you choose the academia route as a primary investigator you are thrown into an environment where you do not have a lot of mentorship experience. Now that I do, I believe I will be a more effective PI in the future.*”

**Building Self-Efficacy**

In reflections from mentors in the research skills course and the mentoring program, they reported having an increase in confidence in scientific research skills or leadership skills. The phenomenon in which an individual has confidence in their ability to do something has been termed *self-efficacy* (Bandura). That self-efficacy would be a theme in both informal and formal mentoring environments was not unexpected, as many other cases have reported self-efficacy increases in other contexts (reviewed in Trujillo and Tanner, 2014).

The self-efficacy theme in the reflections referred to a variety of skills or competencies. In certain cases, the expression of increased self-efficacy was explicit, such as with the following mentor in the research skills course, “*However, I am sure that either this class or being mentor increased my confidence in talking in class.*” One mentor in BUMP applied the skills learned as a mentor to being a mentee in another context: “*I've very much been mentored here just as much as my mentees have, and by mentoring others I've figured out how to get my own mentoring as well.*” Another mentor in BUMP clearly illustrated the growth in self-efficacy through mentoring in this quote, “*I thought I signed up for a simple tutoring job – which would have been very easy since I had all my papers and materials from that class; when Blake emphasized how this was specifically not supposed to be a tutoring job, I sort of panicked because I suddenly felt unqualified to be somebody’s mentor. I had this nagging fear that my mentees wouldn't respect me and I would be completely out of my depth; this was my first ever job and I’ve always been a follower rather than a leader. But with experience I think I’ve learned many good and many bad ideas about mentoring, and I am far more confident about my future than I have ever been. In short, BUMP has been full of challenges and many learning experiences that have allowed me to grow and has greatly helped my chances of having a successful professional career.*”

In general, it is likely that mentors developed confidence in areas not mentioned in the reflections. Possible reasons these were not stated more explicitly could be the mentors perceived importance of these areas, or perhaps the questions addressed within reflection statements were not specific enough.

**IMPACT**

The practice and perpetuation of scientific research requires that incumbent scientists train junior investigators. In this way, new investigators gain skills and competencies necessary to engage in scientific research. Moreover, the ability to win grants and publish papers improves with effective mentoring (Schapira et al.,1992; Palepu et al., 1996; Steiner, et al., 2002; Wingard et al., 2004). Unfortunately, both faculty and student researchers from groups underrepresented in the sciences report a lack of effective mentoring that can limit their participation and success in research (Ginther, 2011; Beech et al., 2013). In fact, at the undergraduate level inadequate mentoring can result in poor research experiences and exit from science (Johnson, 2007). While inadequate research mentoring can cause undergraduates to leave STEM majors, the primary cause of this exit is poor teaching, which is exacerbated for URM students in science (Seymour and Hewitt, 1997). Both of these barriers to undergraduate retention in STEM can be overcome by a near-peer mentoring approach as documented in this dialogue. Our formal and informal near-peer mentoring approaches provided URM undergraduates enrolled in an introductory biology or upper division research skills course with practical information and psychosocial support to succeed in these activities.

Our near-peer mentoring approaches are grounded by the understanding that mentoring is a collaborative process that requires engagement of both teacher and learner. Ideally, mentors/teachers and mentees/learners engage as partners through reciprocal activities to advance the career aspirations of both (Hunt and Michael, 1983). Consequently effective mentoring requires more than occasional meetings between a mentor and mentee, and requires that mentees are not passive recipients of a mentor’s guidance. It is a dynamic reciprocal relationship that changes over time and benefits both parties. This mutually beneficial relationship can occur in learning and/or training research environments where both the mentee and mentor are viewed as “learners and trainees.” In this context the mentee acquires research knowledge and skills needed for scientific productivity, as well as career-related knowledge essential to professional advancement. On the other hand, the mentor gains hands-on experience in effectively supporting the academic and professional growth of junior investigators, thereby honing their skills to effectively guide research projects to success. While theses benefits are commonly accepted for senior research mentors, in this report we find unexpected benefits to mentors engaged in near-peer mentoring. These benefits are similar to those found for peer-led learning environments.

The benefits found for our informal and formal near-peer mentoring approaches have been documented in learning environments where peer-led instruction is utilized. Studies find that peer-led instruction is effective in increasing student persistence, retention and student learning. Both leaders and students benefit from the enhanced learning experience (Lave and Winger, 1991; Cracolice and Deming, 2001; Quitadamo, et al., 2009; Brownel and Swanner, 2010)*.* Peer leaders increase their understanding of the subject matter, develop an increased sense of responsibility and confidence, improve their oral communication skills, and develop an enjoyment of teaching and a greater enthusiasm for pursuing a degree in STEM (Cracolice and Deming, 2001; Hamid, 2001; Smith et al., 2009).

In this report we find that near-peer mentors report benefits that include increased sense of belonging and science identity, as well as improved self-efficacy. These factors are important for increasing persistence of URM students in STEM (Trujillo and Tanner, 2014). Another persistence factor that was identified in a study conducted at SF State and that is also captured in our near-peer mentoring approach is the ability to “give back.” When 22 women of color enrolled in the Cell and Molecular Biology masters program were asked about their ability to persist in science 73% (16/22) reported that they persisted because they had opportunities to use their science skills to “give back” to their communities (Umanzor, 2011). In fact, this communal goal was voiced by several of the mentors in our study, and is an emerging persistence factor for URM students in the sciences (Thomson et al., 2014). Our near-peer mentoring holds significant promise for *amplifying* participation of underrepresented students in science by positively affecting both mentees and mentors.

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Supplemental Material

Appendix A

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| --- | --- |
| Statement | Theme |
| *In terms of my professional life, which at this point in my life I consider to be my work in a research lab on campus, it has helped me develop my communication skills. It has been difficult for me to explain the research I do to people who are not in my field; field-specific terms and jargon may be the easiest way to explain what I am researching, but it means nothing to anyone else. One activity I do with my mentees is that I have them shadow me in lab as I do my daily routine of checking cultures. I even have them do it as well, so that they can experience what is like in a lab. They ask me numerous questions, and I try to explain them to the best of my ability. At first, it was really hard for them to understand what I did. It took me awhile to realize that it wasn’t just that they didn’t understand me, but it was equally my fault in that I was not conveying the research in an effective manner. From this I learned to be patient and to use my creativity in order to answer their questions. I would use analogies to explain the research, and in the end they all could understand at least where I was coming from.* |  |
|  |  |
| *The BUMP Program has helped me apply the way I work with my mentees to the way I work with people in my other duties.* |  |
|  |  |
| *I find it a little challenging to guide group conversations and to be in a leadership position with my mentees because I am naturally more introverted. I am trying to learn to adapt to this new teaching style. I took a year and a half off from school after graduation so I feel like I am just learning how to be a student again. It’s a little out of my comfort zone but I hope that it comes more naturally to me in the future.* | Not ready for the role of mentor |
| *...I didn’t feel like I was on high enough level to be mentoring them. I’m finishing my second year of graduate school- BUT I just finished undergrad school in spring of 2006 and I felt that they were not far behind me.* | Not ready for the role of mentor |
| *At first, it was scary to meet my group. I was in their position not so long ago, so I feel like their equal. It's weird to be in charge.* | Not ready for the role of mentor |
| *Mentoring young students has been challenging to me so far for multiple reasons. One of these is that I am not sure what they want to get out of having a mentor and I am not sure what exactly I have to offer them, so I often have trouble deciding what to talk to them about.* | Not ready for the role of mentor |
|  | Cultivating meaningful relationships |
| *When I asked myself what I could have done better to manage this situation, I had no answers. As a mentor, I asked questions and challenged my mentees, while I provided guidance and encouragement. I was ensured several times by my other two mentees that I was a great mentor, and that they were happy with my mentoring. They always asked me for help when they needed it, and I always gave them the time and respect they deserved from me.* |  |
| *Many different thought went through my head but this nervousness subdued when I found out my group would have two mentors. I thought that the responsibilities would be divided and we could help the mentee better. This was not the case as time went on I found out that it is fully my responsibility as much it is hers. We both had to build a relationship with each student and help them individually as well as in a group setting.* |  |
| *I wanted to be able to help them with anything and I wasn’t sure if I would have enough time to dedicate towards them. Basically, I was nervous because I didn’t want to let them down, and because I didn’t want them to regret that they chose me and not another graduate student.* |  |
| *I really make a conscious effort to make sure that both mentees feel heard. If [student A] volunteers her opinion on a class discussion topic I make sure that I ask [student B] what she thinks. I feel like [student B] is a little more quiet and introverted than [student A] so I make sure that she feels heard too. I really enjoy working with both of them.* |  |
| *I learned a lot about myself and about my mentees. In the end, I felt I learned so much from them too. They even mentored me in the end. I'll miss each of them. I hope they keep me updated on their lives and I hope to see them again in the future...* |  |
| *One of the most significant things I learned about research mentoring is that it takes work from both sides, mentor and mentee, in order to have a successful relationship.* |  |