J Sci Educ Technol (2017) 26:116–126
DOI 10.1007/s10956-016-9656-y

Walking the Path Together from High School to STEM Majors and Careers: Utilizing Community Engagement and a Focus on Teaching to Increase Opportunities for URM Students

Liza Finkel[1]

Published online: 5 October 2016

Abstract Despite decades of efforts to increase the participation of women and people from underrepresented minority groups (URM) in science and math majors and careers, and despite the increasing diversification of the US population as a whole (Planty et al in National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, DC, 2008), participation in STEM majors and STEM careers (including STEM teaching) remains stubbornly male and white (Landivar in American Community Survey Reports, ACS-24, U.S. Census Bureau, Washington, DC, 2013; National Science Foundation and National Center for Science and Engineering Statistics in Special Report NSF 15-311, Arlington, VA, 2015). This paper describes a project with two central goals: (1) to provide opportunities for URM high school students to engage in authentic science and math inquiry with the support of skilled college undergraduate mentors in the hope that these experiences will encourage these high school students to choose and persist in pursuing careers in STEM fields and, even if they do not choose those careers, to feel confident making complex, science or math-based decisions in their everyday lives and (2) to help the mentors (young people, mostly STEM majors) see teaching as a vital, intellectually challenging career that can provide them the opportunity to work for social justice in their communities. While it is unlikely that any one experience will help young people overcome the long odds that face them as they consider either path, our analysis suggests that projects of this kind can make a meaningful contribution to the effort.

Keywords Science teacher preparation · Teacher education · URM participation in science teaching

Introduction

On a rainy day in March 2014, more than 40 high school students from a medium-size city in the Pacific Northwest arrived at the campus of Pacific Northwest College (PNWC), a local liberal arts college. With the support of the undergraduate college students who had mentored them (mostly science and math majors), the high school students were ready to present progress reports on the community-based science and math projects they had been conducting over the past year. These high school and university students were participants in a year-long after-school program, part of a school–university partnership funded by the Howard Hughes Medical Institute (HHMI). The program is designed to increase the participation of students from underrepresented minority groups (URM)[1] in Science, Technology, Engineering and Mathematics (STEM) majors and careers and, at the same time, increase the number of undergraduate STEM college majors who consider STEM teaching as a career.

In this paper I describe the rationale behind the design of the program; the program's structure and participants; outcomes from the first three years of program implementation; and implications for this and other programs with similar goals.

✉ Liza Finkel
lfinkel@lclark.edu

1 Graduate School of Education and Counseling, Lewis & Clark College, Portland, OR, USA

[1] URM—Hispanic, African–American, Native American.

Reconsidering the Pipeline from K-12 Schools to STEM Majors and Careers (Including Teaching)

Despite decades of effort to increase the participation of women and people from underrepresented minority groups (URM) in STEM majors and careers, and despite the increasing diversification of the US population as a whole (NCES 2008), participation in STEM majors and careers remains stubbornly male and white (Landivar 2013; National Science Foundation 2015). This trend persists in spite of considerable research aimed at understanding a constellation of related issues: why URM students don't choose to major in STEM fields (e.g. George et al. 2001; Tobias 1994); why they may not succeed if they do (e.g. Hurtado et al. 2010) or drop out after a short time (e.g. Griffith 2010; National Academy of Sciences 2007); the effectiveness of increased funding to expand access to college and graduate school for URM students in STEM fields; and recommendations for programming designed to increase preparation for and engagement in research for URM students (e.g. Egan et al. 2013; Hurtado et al. 2009; BEST 2004).

The rationales for these efforts cluster around three separate, but not mutually exclusive, concerns, which also largely define the objectives that reformers seek to achieve. Many researchers and policymakers are concerned about the lack of people of color and women in STEM majors and careers primarily for economic reasons. They argue for efforts to increase the percentage of URM participants in these fields to ensure that the USA remains globally competitive (e.g. AIR 2009; NAS 2007; BEST 2004). A second group argues, and I identify more strongly with this view, that the lack of equal participation in and access to STEM majors and careers is a social justice issue, embedded in a historically constructed pattern of marginalization and exclusion (Tate 2001; NSF 2005). Finally, there are those who believe that changing the constitution of the scientific community will transform the practice of science itself, perhaps in ways that bring greater benefits to society, or that benefit a larger and more diverse global community (Lee and Buxton 2010; Barton et al. 2011). Though this is a speculative outcome that I do not take up this paper, I also believe there is considerable reason to pursue this idea.

Regardless of where individuals start in their concern with the lack of diversity in STEM fields, considering what to do about it inevitably leads to an examination of the role(s) played by educational institutions, from backyard preschools to the most prestigious research universities. Some version of the metaphorical pipeline that leads a child from her first curious gaze at the heavens outside her bedroom window to cutting edge post-doctoral research on dark matter in the universe is a resoundingly common narrative in this landscape. So is the "one teacher who changed my life," the teacher who opened up the world of science and helped show a student the path forward, often past challenges related to looking quite different than the scientists who appeared in their textbooks or on the evening news.

The problem with these beguiling images is hardly that they are unwelcome or untrue—indeed, they are deeply moving, incredibly important to share, and certainly worth celebrating. What often recedes into the background of these narratives, however, is another extraordinarily important thing that may well have been happening in that same classroom. While our potential world changing young scientist took her first steps toward life as a scholar, many more students who faced similar barriers and obstacles came to understand the power of science as a form of knowledge and set of skills that every citizen might use to achieve their goals. Indeed, these experiences might have been (in the long run) just as transformative and life changing, regardless of where the students' interests took them. But the path that these students travel is more difficult to track and the impact of increasing the number of URM students who enter STEM and STEM teaching fields even more important to explore.

Full participation in our increasingly complex and interdependent global community requires the capacity to understand and utilize science and math concepts for the purpose of individual and collective participation in decision making—whether individuals choose careers in science and math or not. Making decisions about limiting the sale of jumbo-sized sugary drinks, labeling GMO foods, expanding the use of nuclear energy, or fluoridating a community's water, requires that all citizens have the capacity to understand and apply scientific and mathematical knowledge in their everyday lives as well in support of the public good. Without the participation of all members of our community in these kinds of decisions—as scientists, doctors, computer programmers, engineers, mathematicians, as well as citizens—historical patterns of inequity and disparity in the distribution of society's benefits and burdens are likely to be sustained or even worsened over time.

As noted, K-12 public schools are widely recognized to occupy a pivotal position in helping young people to develop the knowledge, skills, and dispositions needed to participate actively in these forms of deliberation. Recruiting and preparing K-12 teachers who are prepared to teach science and math to an increasingly diverse group of students is a crucial element in encouraging and supporting more URM students and women to pursue majors and careers in the sciences. An important component of that effort is the recruitment of students of color into teaching. In spite of efforts to recruit more teachers of color, the number of minority teachers still falls far below that of the steadily increasing number of students of color in schools (Villegas et al. 2012). Studies also indicate that teachers of color leave the teaching field earlier and in higher numbers than white teachers (Ingersoll and May 2011a; Achinstein et al. 2010). Given this situation, it important to increase and broaden our efforts to recruit and retain teachers of color. It is also essential that we ensure that all teachers, whatever their race or ethnicity, who enter K-12 science and math classrooms are prepared to teach in culturally relevant ways (Ladson-Billings 2009; Gay 2010).

A second key leverage point in K-12 schooling involves the nature of the science curriculum itself and the forms of pedagogy used in classrooms. Considerable research suggests that many students, particularly girls and URM students, find science unattractive because the topics covered are perceived as uninteresting, unrelated to students' lives outside of school (Christidou 2011), and disconnected from the knowledge of science that students bring into the classroom (Barton et al. 2011). These forms of pedagogy reflect scientific practice that is too distant from students' experiences and the problems or questions they face in their communities (Brickhouse et al. 2000). Successfully addressing this challenge requires more than changing the curriculum content of the science being taught, it requires "positioning the learner as a growing member of a community, with expanding roles and responsibilities (Freire 1970)" (cited in Barton et al. 2011), and broadening the views of the communities and people who engage in science as citizens and as scientists (Eisenhart and Finkel 1998).

The project described below aims to integrate two elements of the STEM pipeline for URM students. It aims at the traditional goal of supporting URM students as they consider STEM majors in higher education and related careers. It also, however, recognizes the importance of recruiting URM students into STEM *teaching* fields and changes in science teaching as essential structural components to the overall success of the pipeline. Connecting the recruitment and preparation of science teachers, especially URM teachers, to a conception of science rooted in the real-world experiences of communities has been an essential component missing from previous efforts aimed at increasing the presence of URM students in STEM majors and careers. Key also here are the forms of pedagogy that all teachers practice in the classroom, which implicates teacher preparation programs in this effort as well. Ingersoll et al. (2012), for example, report that while STEM teachers "are more likely [than teachers in other disciplines] to have received their bachelors degrees from the most selective colleges and universities…[and] are also more likely than other new teachers to have earned a master's degree or a doctorate," they are also more likely to report that they have pursued a non-traditional route into teaching and that they have had less pedagogical instruction than other teachers. This study also found that it is this pedagogical preparation that separates early career teachers who remain in teaching from those who leave after a short time—more pedagogical preparation leads to greater retention (Ingersoll et al. 2012).

Improving our efforts to build the pipeline for URM students in STEM fields requires systematically addressing the mutually reinforcing limitations that are constituted by a lack of diversity in the science and math teaching professions (from K-12 schools to higher education), as well as science and math curricula and instructional methods (again, from K-12 schools to higher education) that fail to connect STEM knowledge and understanding to the real-life concerns and problems that we face in our communities. By integrating these efforts, we can help students recognize that majors and careers in the STEM fields offer singular opportunities not only to pursue their own goals, but to bring about more a just and equitable society through the forms of deliberation that these skills and forms of knowledge allow. These elements constitute the rationale for the HHMI Community Engagement and Leadership in Science (CELS) Program described in this paper.

The HHMI CELS Program: A Framework for Collaboration and Inquiry

The HHMI CELS program is a partnership between the College of Arts and Sciences (CAS) and the Graduate School of Education and Counseling (GSEC) at PNWC, and five high schools located in the surrounding metropolitan region. It has two central goals: 1) to provide opportunities for URM high school students to engage in authentic science and math inquiry with the support of skilled college undergraduate mentors in the hope that these experiences will encourage the high school students to choose and persist in pursuing careers in STEM fields and, for all students, to feel confident participating in civic dialogue and deliberations regarding matters that require scientific and mathematical knowledge and skills; and 2) to help the mentors (young college students, mostly STEM majors) see teaching as a vital, intellectually challenging career that can provide them the opportunity to work for social justice in their communities. In a social climate where young people frequently hear instead that teaching is a low status career, and where teachers are only required to "teach to the test," we hope to help them develop a vision of teaching as active, engaged, and meaningful.

In light of the need to improve the preparation, recruitment, and retention of more, and more diverse, STEM teachers, the HHMI CELS program is designed to encourage a diverse group of undergraduate STEM majors to explore teaching as a career. Recognizing that "the strongest factors [affecting retention] by far for minority teachers were the level of collective faculty decision-making influence in the school and *the degree of individual instructional autonomy held by teachers in their classrooms*" [emphasis added] (Ingersoll and May 2011b), the program provides CELS scholars with the chance to work closely with groups of high school students, many from groups underrepresented in science and math, and to develop the skills needed to make meaningful educational decisions about how to teach in ways that are connected to the high school students' interests and communities and that engage those students in authentic, self-identified, inquiry projects.

Prior to the development of this program, undergraduate students at PNWC who were interested in exploring STEM teaching careers had few formal pathways to follow. Although PNWC has a highly respected graduate school that offers several teacher preparation programs, only three education courses were offered for PNWC undergraduate students, none focusing specifically on science education. As a result of an earlier HHMI-funded grant, faculty became aware of the number of students interested in pursuing careers as teachers and this program was created in part to encourage more purposeful collaboration between the two campuses in order to support those students. While this project is not intended to replace the intense and focused pedagogical preparation of a formal, university-based teacher education program (indeed, the idea is to introduce prospective teachers to the challenging and intellectual work of teaching and encourage them to pursue just such a program), we take seriously the claim that pedagogical preparation is important in the development of new teachers, particularly if we are interested in ensuring that they remain in teaching.

During the academic year after-school program, CELS scholars help high school students identify, plan for, and carry out community-based inquiry projects that require the application of science and/or math content and skills. In addition, high school students who participate in the academic year after-school program are eligible to apply for paid summer research internships in research labs at the college and at another local research campus. This is another strategy to increase students' exposure to authentic science and math experiences and encourage them to consider further study and perhaps careers in STEM fields. During the summer research internship program, high school students are paired in research labs with undergraduate students who serve as on-site mentors.

The CELS academic year program begins each fall with the recruitment of undergraduate students who are interested in exploring careers in science or math teaching. Students apply to be Team Leaders or Team Members and are selected based on following criteria: experience working with young people in educational settings (e.g. volunteering in schools, serving as camp counselors, or tutoring); prior experience in science and/or math; and experience in leadership roles. Five CELS teams are formed, each with a Team Leader and three Team Members. Team Leaders meet with members of the HHMI Outreach Team (educators with experience in science and math teacher education, and in community-based education) once a week to discuss the work going on at their high school sites and to address issues that arise there. CELS teams also meet with the Outreach Team once a month for 2-h professional development workshops designed to support the teams' work with students at their school sites to identify, plan for, and carry out community-based inquiry projects.

CELS teams worked with high school students enrolled in five metro area schools: two comprehensive public high schools;[2] one public health and science magnet school; one public alternative school; and one private Catholic high school. All of the schools were chosen because they enroll a significant number of URM students and because they were eager to find ways to encourage more students from those groups to explore post-secondary education in STEM fields. The schools all agreed to identify a teacher who would serve as a program liaison, help to recruit high school student participants, particularly those from groups underrepresented in math and science careers, welcome and support the CELS teams when they arrived at the school each week, ensure that the teams had a place to meet with their students, and assist with logistical challenges associated with things like field trips, laboratory safety, and locating necessary materials while at the school site.

To support CELS teams before and during their work at their school sites, the HHMI Outreach Team organized monthly 2-h professional development sessions for CELS team members. The team was led by the HHMI Faculty Fellow, a science educator with experience in teacher preparation as well as expertise in strategies for engaging diverse learners in authentic science inquiry (Eisenhart and Finkel 1998; Finkel et al. 2007). Topics covered in professional development sessions included the following:

- An overview of recent research on learning and factors that inhibit persistence and engagement of students, particularly those from URM groups or who might be the first in their families to pursue higher education.
- Strategies for engaging high school students in meaningful science learning, including an introduction to

[2] After the 2013–14 year, one of these two high schools chose to withdraw from the program; we replaced them with another, similar, public high school.

using "backwards planning" (Wiggins and McTighe 2005) as a method for unit and lesson planning,
- Examples (written and filmed) of students engaging in authentic, community-based inquiry projects.
- Methods for helping students choose a topic and develop, refine, and implement an inquiry plan.

Most sessions include time to reconnect as a large group, introduce and discuss new content, and an opportunity for CELS teams to work together and get one-on-one support from Outreach Team staff on issues specific to the work they are doing with students at their school site.

A second and equally important part of the program occurs each summer, as undergraduate and high school students are invited to apply for paid summer research internships as a part of the CELS Summer Scholar Program. Undergraduate and high school students chosen for the program are paired on faculty-led research projects where, using what we call a "laddered" mentoring model, high school students are mentored directly by undergraduate students who are in turn mentored by the faculty researcher and/or by post-doctoral students working with the faculty. Undergraduate students, recruited from STEM majors on the campus who may or may not have served on a CELS team prior to applying, are chosen based on their interest in mentoring a high school student over the summer as well as the strength of their background in science and/or math. High school students who have participated in the academic year program are encouraged to apply and are selected on the basis of their academic record, recommendations from a teacher at their school and from a CELS team member. Face-to-face interviews are conducted with the faculty researcher who will head the laboratory where they will be working. Undergraduate internships last for 10 weeks and high school internships for 8. Undergraduate mentors start approximately 2 weeks prior to the arrival of their high school mentees. This allows the undergraduate mentors to prepare for the arrival of the high school students and to ensure that the student is supported in their work from their first day "on the job".

In order to support the work of CELS Summer Scholars, all participants attend weekly seminars. The weekly seminars for undergraduate scholars are taught by an experienced high school science teacher, who also serves as a liaison at one of the academic year school sites. These seminars focus on learning about and implementing mentoring skills in support of their high school student mentee. The weekly seminars for high school scholars are taught by a member of the Outreach Team with a background in sociology and community-based outreach. These seminars focus on increasing students' confidence in their ability to pursue further study in STEM fields and on helping the students see the ways that science and math knowledge can be used as tools to work for social justice in local communities.

Assessing Progress Toward Program Goals

The 2013–14 academic year was the second year of the grant, but in many ways the first year in which CELS teams were fully implemented, in part because of the addition of the HHMI Faculty Fellow (the author of this paper). Two major program changes were implemented at the start of the second year. First, we increased the number of undergraduate students employed on the CELS teams from 15 to 20, with the goal of ensuring that each of our five school sites had a team of four students working there and that no team member would ever need to visit a school site on his or her own. We also sought to increase the percentage of URM students on the CELS teams by collaborating with a number of offices on campus in the hopes of getting more URM students to become aware of the opportunity and to consider applying. These recruitment efforts paid off (Table 1). Facing considerable challenges, the program managed to double the number of URM students participating in the first year.

Second, although CELS teams had been working at local high schools for several years, prior to the Fall 2013 semester the after-school program was centered around weekly science demonstrations prepared and put on by undergraduates, followed by one-on-one tutoring and homework help in science and math. The focus of the work shifted to one that emphasized using research-based science and math education teaching practices to more fully engage high school students in authentic inquiry. This new focus also required the development of the monthly professional development sessions described above.

There were two reasons for the shift from what we describe as the STEM "entertainment" approach (using exciting demonstrations to attract students to after school

Table 1 Make-up of CELS teams, by year

	Number of CELS team members	Number of URM CELS team members
Year one	15	2 (13 %)
Year two	20	3 (15 %)
Year three	26	5 (19.2 %)

tutorial and homework help sessions) to the STEM "engagement" approach (engaging high school students in identifying areas for inquiry and working with them to plan and carry out year-long investigations in local contexts). First, for the undergraduate students working on the CELS teams, we wanted to focus on developing pedagogical skills in line with research on best practices in science and math education in order to help them come to see science and math teaching as a career that involves teachers and students in active roles, making choices and participating in meaningful, community-based learning. It was our hope that this kind of experience would lead them to be more likely to consider teaching as a career.

A survey administered at the end of Year Two to all CELS team members from years One and Two revealed that 15 of the 20 CELS participants who responded (of a possible 35 participants) were interested in exploring a career in teaching and that 15 of the 20 also felt that participating in CELS made them more likely to pursue a career in teaching (Table 2). At the time the survey was administered, 4 of the 20 respondents were already pursuing careers in education (since many CELS participants were still enrolled undergraduates at the time, this small number is not surprising). The survey was administered again at the end of Year Three to all Year Three CELS team members, and again, a most of the students agreed that they were interested in pursuing a career in teaching, and that participation in CELS had made them more likely to consider that career (Table 2).

Second, we found that high school student participation was intermittent when the main reason to attend after-school sessions was viewing a science demonstration and getting help with homework. Research on educational interventions designed to encourage increased participation by girls and students of color has demonstrated that students are both more engaged, and learn more, when they participate in inquiry projects that are situated in their local communities and are relevant to their interests (e.g. Brotman and Moore 2008; Barton 2003). We hoped that high school students would be more likely to persist when they had a voice in developing a community-based project that would be carried out over the course of a full academic year than when the main focus of each session was coming to watch a science demo (no matter how entertaining) and get help with homework or other science or math assignments.

Comparing high school students' attendance in the academic year program from year one (2012–13) through year three (2014–15), we found that there was a considerable increase in both the absolute numbers of students who were "significantly served" (in year one these were students who had more than 10 h of contact with the CELS teams, in years two and three these were students who participated for the full year), and in the number of significantly served URM students (Table 3). However, the number of students who participated for some portion of the program but were not significantly served was almost the same in both years (13 in year one, 12 in year

Table 2 Interest in pursuing teaching as a career

	Interested in exploring teaching as a career		Participation in CELS made me more likely to pursue teaching		Solid plan to pursue teaching career OR currently pursuing teaching career	
	Years 1 and 2	Year 3	Years 1 and 2	Year 3	Years 1 and 2	Year 3
Agree/strongly agree	15 (75 %)	20 (76.9 %)	15 (75 %)	22 (84.6 %)	4 (20 %)	8 (30.8 %)
Disagree	5 (25 %)	6 (23.1 %)	5 (25 %)	4 (15.4 %)	16 (80 %)	18 (69.2 %)

Table 3 HS participant comparison

	Total # of HS participants	Significantly served[a] students	Significantly served URM students	Significantly served students who applied for summer internship	URM students who applied for summer internship[c]	URM students who were selected for a summer internship
Year one	38	25[a]	17	17	NA	9
Year two	64	52[b]	31	25	13	6
Year three	62	49[b]	34	25	16	9

[a] Significantly served students in Year One had greater than 10 h of participation

[b] Significantly served students in Years Two and Three had a full year of participation

[c] All URM students who applied and were selected for a summer internship were significantly served students

two, 13 in Year Three). In addition, the number of participants in the after-school program who chose to apply for summer internships increased considerably from 16 applicants in year one to 25 applicants in year two. Numbers for year three are similar to those from year two, showing small increases in the number of significantly served URM high school students (from 31 to 34), an increase in the number of URM students who applied for a summer internship From 13 to 16 students), and an increase from 6 to 9 URM students selected for a summer internship.

Perhaps more notable is the increase in numbers of URM students served when compared with the numbers served in an earlier iteration of the grant, also funded by HHMI (Table 4). Over the 4 years of the earlier grant period, a total of 23 URM high school or community college students were significantly served during academic year programs; after 3 years of the second grant, 82 URM high school students have already been significantly served.

While there were other differences between the two grant projects (one being that the earlier grant targeted both high school and community college students), perhaps most important with regard to these numbers is the focus on recruiting undergraduate students interested in pursuing careers in education to work with the high school students, which led to the implementation of monthly professional development sessions for CELS scholars that emphasize how to successfully lead this kind of work, a well as the efforts made to work with high school liaisons to recruit URM students for the program, and the focus on engaging with high school students on community-based inquiry projects during the after-school program, rather than focusing on one-on-one tutoring and homework help.

Despite what appears to be a trend toward an increase in the number of URM students served, a closer look at the attendance data from Year Two (2013–14) of the current grant revealed some other patterns, particularly with regard to the participation and persistence of URM students (Table 5). While the number of students who stopped attending after the fall semester in Year Two was relatively low, ranging from a high of five students at one site (50 % of those who began the program at that site) to as low as one student (0.05 % of those who began the program at that site) at another, and while there could be many reasons that students no longer chose to attend, it is worrisome that at 4

Table 4 High school/community college students served by HHMI Programs between 2008 and 2011

	Total # of participants	Significantly served[a] students	Significantly served URM students	Significantly served students who applied for summer internship	Significantly served URM students who applied for summer internship	URM students who were selected for a summer internship
2008–2011	95	61	23	NA	NA	7

[a] Significantly served students are those with greater than 10 h of participation in a given year of the project

Table 5 Participation and demographic information for CELS HS participants by school (years 2 and 3)

	GHS[a]	NCHS	DLSNC		CHS		HS2		RAHS		Total	
	Year 2	Year 3	Year 2	Year 3	Year 2	Year 3	Year 2	Year 3	Year 2	Year 3	2	3
# of Participants in Fall	10	11	12	12	13	7	19	24	10	9	64	62 %
URM Participants in Fall	7	3	11	10	4	4	11	17	8	6	41	40
	70 %	27 %	92 %	83 %	31 %	57 %	58 %	71 %	80 %	67 %	64 %	65 %
# of Participants in Spring	5	5	11	12	11	4	18	22	7	6	52	49
URM Participants in Spring	4	1	10	10	2	2	10	16	5	5	31	34
	80 %	20 %	90 %	83 %	18 %	50 %	56 %	73 %	71 %	83 %	60 %	69 %
# (%) of loss that were URM students	3	2	1	0	2	2	1	1	3	1	10	6
	60 %	33 %	100 %		100 %	67 %	100 %	50 %	100 %	33 %	83 %	43 %
# of Summer Internship Applicants	3	1	4	9	6	3	8	9	4	3	25	25
URM Summer Internship Applicants	2	0	4	7	1	1	3	6	3	2	13	16
											52 %	64 %
# of Accepted Summer Interns	1	1	3	5	2	2	3	4	2	1	11	13
Accepted URM Summer Interns	1	0	3	5	1	0	0	3	1	1	6	9
											55 %	69 %

[a] After Year 2 GHS withdrew from the program and was replaced with NCHS

of the 5 sites 100 % of those who stopped attending were URM students (at the fifth site, the one with the largest overall attrition rate, 60 % of those who stopped attending were URM students). And, despite the fact that almost 60 % of full year program participants were URM students, only 52 % of the applications for summer internships came from URM students. Finally, while URM participation has increased overall since the previous HHMI grant and even since Year One of this grant, the number of URM student participants in Year Two varies considerably from high school site to high school site, from a high of just over 90 % at one, to a low of less than 20 % at another. Comparing Year Two with Year Three, two of the four continuing sites increased the percentage of URM students participating in the fall, and although all of the sites had some attrition between the fall and spring semesters, all four of the continuing sites reduced the rate of attrition for URM students. Overall, in Year Three, the percentage of URM high school participants remained stable in the fall, and the percentage of attrition between fall and spring that was due to URM students leaving the program decreased from 83 to 43 % (Table 5).

More Work on the Pipeline: Lessons Learned

Based on the emerging data presented above, that there are several ways that the work of the grant provided an opportunity for an increasing number of URM students to participate in authentic and engaging science and math projects with the help of undergraduate students prepared to facilitate those projects. In other areas, there is still more work to be done.

Over the first 3 years of the program, there has been an increase both the total number of students served and the number of URM student participants. The number of URM students hired as CELS team members has also increased. There was also very little attrition among high school students at most of the sites, with the exception of the comprehensive high schools where at one site 50 % of the students stopped attending by the midway point of Year Two; in Year Three, overall attrition at the two comprehensive high schools was 55 % at one and 57 % at the other. The sites with the highest amount of attrition were also the sites with the most variable amount of site teacher involvement. In these sites, there was greater turnover in teacher participation and generally lower rates of attendance at program events. As one might expect, this comparative lack of engagement negatively affected student engagement and persistence. This result tracks with our belief in the importance of the relationships that are at the foundation of any attempt pipeline building.

There was, however, some attrition at all sites, and that attrition, particularly in Year Two, was largely due to URM students leaving the program. Overall, in Year Two, 83 % of the attrition from sites was due to the loss of URM students. Although the absolute numbers of students who left were small (ranging from 1 to 3 students at the 4 sites with 100 % URM attrition), and the percentage of URM students leaving in Year Three was considerably less, in a program specifically designed to support URM students, this is still of considerable concern.

Because the college academic calendar includes a longer winter break than that in the high school calendar, we worried that persistence might be affected by the lack of program continuity over the long winter break. In order to address this, in Years Two and Three, we recruited a group of students in the PNWC Graduate School's School Counseling Program to meet with high school participants in December and January. This school counseling program focuses on issues of access, building the culture around college attendance, and explicitly addresses structural issues of inequality. Focusing their sessions on advice related to preparing for, choosing, and applying to college, these meetings provide clear value for students and their families and thus incentive for students to continue to attend the after-school program.

The number of high school participants who applied for summer internships at the end of year two almost doubled compared to the first year of the program, and increased more modestly, from 13 to 16, in year three. Despite this trend, there is also some reason for concern. One CELS team leader reported that some of the URM students at her site chose not to apply for a summer internship because they did not feel qualified and thought they would not be able to compete successfully with the White students who also applied (CELS team leader, personal communication). Addressing this mindset on the part of the URM high school students at our sites, particularly those where the majority of the participants are not URM students, is essential if we are going to continue to increase URM participation in this project and in STEM fields more broadly.

An increase in the number of summer applicants does not immediately translate into greater opportunities, however, as there remain a fixed number of internship positions. As more students apply, the competition for research internships increases. Research on factors influencing the success and persistence of URM students in STEM majors suggests that participation in an early research experience is a key to success (Sadler and McKinney 2010), so the opportunity to complete a summer research internship can be an important factor in supporting these students in pursuing majors and careers in STEM. So far, we have been able to ensure that all students who apply have the chance to interview with at least one faculty researcher, so that students all get to meet and talk with a potential mentor, but we cannot provide an internship for all applicants.

We would like to develop an alternative research opportunity for those students who do not get selected for an internship. One possible option that we are exploring is the Howard Hughes Medical Institute (HHMI) Science Education Alliance Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES) program. This course has been implemented with over 4800 undergraduate students at 73 institutions (Jordan et al. 2014) and shows promise as a less expensive, but still authentic, research experience that can provide access to more students than a one-on-one research internship. Because many of the URM high school students we work with depend on the income from a summer job to contribute to their family income and/or save for college, it is essential that any alternative we develop provide some kind of stipend for participants in order to ensure their participation, so this is an additional challenge we will need to overcome.

As indicated at the start of this paper, toward the end of the program in March (year two) and April (year three) high school students from the five participating high schools come to the PNWC campus for the Annual CELS Spring Symposium. CELS team members work with their high school participants to prepare a formal presentation describing their projects, to date. Students from all high schools attend and present PowerPoint or Prezi reports describing the questions they are investigating and how and why they chose it, the process they are using for their investigation, what they have learned so far, and what their next steps might be. The high school student participants who present their work at the Symposium are confident, professional, and prepared. The work that the CELS undergraduate scholars have done to help the students is evident and the scholars themselves proudly watch as their students described their projects and easily responded to questions from the audience.

Despite these successful presentations in the spring, high school students at all five sites struggle to be ready to begin data collection before early February, limiting data collection and time for data analysis. Although we anticipated that CELS teams would face challenges initiating inquiry-based projects with high school students, an instructional practice that is challenging for even experienced science and math teachers, we still underestimated the amount of time and professional development required to prepare CELS teams. Working with CELS teams even earlier in the year and helping them to develop more explicit plans for identifying inquiry projects and beginning to collect data are ongoing priorities in professional development sessions.

We also found that over the course of the project, the liaison teachers at our sites began to take a larger role in the after-school program; increasing their efforts to recruit URM students, formalizing their recruiting process, and supporting the work of the CELS teams as they identify and carry out their inquiry projects. This increased interest in the program by teachers at partner school sites suggests to us that the program is having an impact on the high school students who participate and that the teachers at our sites find the program a valuable use of their time. However, at all three of the large comprehensive high schools where we have worked, site teachers are difficult to recruit and are less involved than the teachers at the other, smaller, non-traditional schools. In addition, finding a time to meet after school when students are not already committed to other after-school activities has been difficult, and recruitment at these large high schools has not been as successful as at other sites either resulting in small groups of students at the start of the year, and/or significant attrition as the year progresses.

Finally, we have found that clearly communicating with the teachers who serve as site liaisons about the goals of the program, as well as about the expected roles that the teacher liaison can be expected to play, is essential. At the schools where teacher communication was less consistent, we had fewer high school participants and CELS teams faced more challenges navigating the logistics associated with working in a school (such as arranging field trips, finding supplies and other resources at the school, and encouraging student participation). On the other hand, at the schools where the teacher liaison took too dominant a role, it was difficult for CELS teams to ensure that projects that were developed came from ideas generated by the high school students and not from the teacher.

Conclusion

The multiple goals of the project described in this paper are clearly complex and not easily accomplished. Encouraging undergraduate STEM majors to explore teaching careers in the current educational climate with its focus on external accountability through standardization of both curriculum and assessment, and where teaching is a career held in far lower esteem than other careers STEM majors might pursue, is a significant challenge. Equally, if not more, challenging is the goal of increasing the participation of URM students in STEM majors and careers, as evidenced both by considerable research on reasons for and efforts to increase their limited participation and by even a casual review of the persistently low numbers of URM participants in those fields.

What this project attempted to do, however, was to engage the complexity of the pipeline model and explore the structural elements, or challenges, that need to be considered in effectively achieving its broader goals. These elements include the pedagogy of science instruction and the conception of science as embedded in social, cultural, economic, and other aspects of collective experience. They include the nature of teacher preparation and collaboration between colleges and k-12 schools. And they involve the bridges that help high schools students make the transition, in thought as much as practice, to a successful experience in higher education.

It is unlikely that any one experience will help young people overcome the long odds that face them as they consider either path. However, based on the work of this grant, we are hopeful that the program described here can make a contribution to the efforts of schools, colleges and universities, local communities, and national policy-makers in improving the odds that young people who are interested in teaching see that career as one that is intellectually challenging, personally fulfilling and of value to society as a whole and in helping more URM high school students see the possibility of pursuing further education in STEM fields.

References

Achinstein B, Ogawa R, Sexton D, Freitas C (2010) Retaining teachers of color: a pressing problem and a potential strategy for "hard-to-staff" schools. Rev Educ Res 80(1):71–107

American Institutes for Research (2009) The road to the STEM professoriate for underrepresented minorities: a review of the literature. American Institutes for Research, Washington, DC

Barton A (2003) Teaching science for social justice. Teachers College Press, New York

Barton AC, Basu J, Johnson V, Tan E (2011) Introduction. In: Basu SJ, Barton AC, Tan E (eds) Democratic science teaching: building the expertise to empower low-income minority youth in science. Sense Publishers, Rotterdam

Brickhouse N, Lowery P, Schultz K (2000) What kind of a girl does science? The construction of school science identities. J Res Sci Teach 37(5):441–458

Brotman JS, Moore FM (2008) Girls and science: a review of four themes in the science education literature. J Res Sci Teach 45(9):971–1002

Building Engineering and Science Talent (BEST) (2004) A bridge for all: higher education design principles to broaden participation in science, technology, engineering and mathematics. BEST, San Diego

Christidou V (2011) Interest, attitudes and images related to science: combining students' voices with the voices of school science, teachers, and popular science. Int J Environ Sci Educ 6(2): 141–159

Egan MK Jr, Hurtado S, Chang MJ, Garcia GA, Herrera FA, Garibay JC (2013) Making a difference in science education: the impact of undergraduate research Programs. Am Educ Res J 50(4): 683–713

Eisenhart M, Finkel L (1998) Women's science: learning and succeeding from the margins. The University of Chicago Press, Chicago

Finkel L, Greene K, Rios J (2007) Accommodating student diversity within inquiry. In: Abrams Eleanor, Southerland Sherry, Silva Peggy (eds) Inquiry in the classroom: challenges and opportunities. Information Age Publishing, Greenwich

Freire P (1970) Pedagogy of the oppressed. Herder & Herder, New York

Gay Geneva (2010) Culturally responsive teaching: theory, research and practice, 2nd edn. Teachers College Press, New York

George YS, Neale DS, Van Horne V, Malcom S (2001) In pursuit of a diverse science, technology, engineering, and mathematics workforce: recommended research priorities to enhance participation by underrepresented minorities. American Association for the Advancement of Science, Washington DC

Griffith A (2010) Persistence of women and minorities in STEM field majors: is it the school that matters? Econ Educ Rev 29(6):911–922

Hurtado S, Cabrera N, Lin MH, Arellano L, Espinosa LL (2009) Diversifying science: underrepresented student experiences in structured research programs. Res High Educ 50(2):189–214

Hurtado S, Newman CB, Tran MC, Chang MJ (2010) Improving the rate of success for underrepresented racial minorities in STEM fields: insights from a national project. New Dir Inst Res 2010(148):5–15.

Ingersoll RM, May H (2011a) Recruitment, retention and the minority teacher shortage. Consortium for Policy Research in Education. CPRE Research Report #RR-69

Ingersoll RM, May H (2011b) The minority teacher shortage: fact or fable. Phi Delta Kappan 93(1):62–65

Ingersoll R, Merrill L, May H (2012) Retaining teachers: how preparation matters. Educational Leadership. 69:30–34

Jordan TC, Burnett SH, Carson S, Caruso SM, Clase K, DeJong RJ, Dennehy JJ, Denver DR, Dunbar D, Elgin SCR, Findley AM, Gissendanner CR, Golebiewska UP, Guild N, Hartzog GA, Grillo WH, Hollowell GP, Hughes LE, Johnson A, King RA, Lewis LO, Li W, Rosenzweig F, Rubin MR, Saha MS, Sandoz J, Shaffer CD, Taylor B, Temple L, Vazquez E, Ware VC, Barker LP, Bradley KW, Jacobs-Sera D, Pope WH, Russell DA, Cresawn SG, Lopatto D, Bailey CP, Hatfull GF (2014) A broadly implementable research course in phage discovery and genomics for first-year undergraduate students. MBio 5(1):e01051–13

Ladson-Billings G (2009) The dreamkeepers: successful teachers of African American children, 2nd edn. Jossey Bass Publishers, San Francisco

Landivar LC (2013) Disparities in STEM employment by sex, race, and Hispanic origin. American Community Survey Reports, ACS-24, U.S. Census Bureau, Washington, DC

Lee O, Buxton CA (2010) Diversity and equity in science education: research, policy, and practice. Teachers College Press, New York

National Academy of Sciences (2007) Rising above the gathering storm: energizing and employing America for a brighter economic future. National Academies Press, Washington DC

National Science Foundation (2005) Broadening participation through a comprehensive, integrated system. National Science Foundation, Arlington

National Science Foundation, National Center for Science and Engineering Statistics (2015) Women, minorities, and persons with disabilities in science and engineering: 2015. Special Report NSF 15-311. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/

Planty M, Hussar W, Snyder T, Provasnik S, Kena G, Dinkes R, KewalRamani A, Kemp J (2008) The condition of education 2008 (NCES 2008-031). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, DC

Sadler TD, McKinney L (2010) Scientific research for undergraduate students: a review of the literature. J Coll Sci Teach 39(5):43–49
Tate W (2001) Science education as a civil right: urban schools and opportunity-to-learn considerations. J Res Sci Teach 38(9): 1015–1028
Tobias Sheila (1994) They're not dumb, they're different: stalking the second tier. The Research Corporation for Science Advancement, Tucson
Villegas AM, Strom K, Lucas T (2012) Closing the racial/ethnic gap between students of color and their teachers: an elusive goal. Equity Excell Educ 45(2):283–301
Wiggins G, McTighe G (2005) Understanding by design, expanded, 2nd edn. Association for Supervision and Curriculum Development, Alexandria