GPS: Geoscience Partnership Study

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ABSTRACT

To promote and expand geoscience literacy in the United States, meaningful partnerships between research scientists and educators must be developed and sustained. For two years, science and education faculty from an urban research university and secondary science teachers from a large urban school district have prepared 11th and 12th grade students to mentor 7th grade students on the topic of climate science. This partnership was based on the premise that high school students, when trained and supported by teachers and scientists, have the capacity to extend middle school students' efforts to engage in and understand the geosciences. This paper a) describes mentors' and mentees' understandings of climate science as a function of their participation in the second year of this program, b) identifies the characteristics of effective mentoring relationships, and c) explores the scalable and sustainable aspects of this partnership.

INTRODUCTION

As recently reported in the 2009 GEO VISION Report, geoscientists in the future will increasingly be called to assess how human behavior is impacting Earth and its systems (NSF Advisory Committee for Geosciences, 2009). As reported by the 2009 Earth Science Literacy Principles Report (Earth Science Literacy Initiative, 2009), science educators are uniquely positioned to translate the big ideas of earth science into language and learning opportunities that can be understood by all K-12 students. According to this report, an earth-science-literate person

- understands the fundamental concepts of Earth's many systems;
- knows how to find and assess scientifically credible information about Earth;
- communicates about earth science in a meaningful way;
- is able to make informed and responsible decisions regarding Earth and its resources; and
- recognizes that earth scientists use repeatable observations and testable ideas to understand and explain our planet.

To achieve this level of literacy, federal agencies have begun to place a greater emphasis on the importance of developing and disseminating K-12 earth science educational materials, instructional approaches, and programs that will help prepare the next generation of scientists and informed citizens (United States Global Change Research Program, 2009; Ward, 2009).

Unfortunately, many of these new initiatives will be--or are being--introduced into systems where the earth sciences are not an integral part of secondary science education curricula. Historically less than 10% of all high school students in the United States have had the opportunity to take a class in the earth sciences (Chief State School Officers Council, 2001, 2003). In 2002, only 11% of America's 8th graders participated in an earth science course (Chief State School Officers Council, 2003). From 1982 to 2005, less than a quarter of the students from each graduating high school class had taken an earth science or geology course (American Geological Institute, 2009).

One of the most important indicators of high school students' choice of, pursuit of, and persistence in an undergraduate science degree is whether they have participated in advanced science and mathematics courses as part of their high school experience. In the state where this study took place, even though the percentage of students taking Advanced Placement exams in science and math is consistent with national averages, the percentage of African-American and Hispanic students taking Advanced Placement exams in science and math is less than half the national average (Russell and Atwater, 2005). Furthermore, the level of science proficiency that middle school students in high-poverty areas attain often determines whether they continue to pursue science in high school and beyond (Ruby, 2006). Considering that that the current number of geoscientists in the United States is not sufficient and representative of its population, special efforts need to be extended that promote earth science education in a variety of demographic settings.

To help ensure that middle and high school students in impoverished contexts experience a high-quality science education; adequate resources, high-quality curricula, and meaningful programs must be made available to qualified teachers (Atwater, 2000). Ultimately, meaningful geoscience partnerships need to be established that support teachers so that they can work with students to transcend the "pedagogy of poverty," or factors in classrooms that make it difficult to implement effective science programming (Bransford et al., 2002; Songer et al., 2003, p. 491; White and Frederiksen, 1998).

THEORETICAL FRAMEWORK

According to Maton, Hrabowski, and Schmitt (2000), institutions that achieve the objective of creating sustainable programs that are supportive of underrepresented students' pursuit of the sciences usually contain certain characteristics such as summer programs, study groups, mentoring, and research opportunities. Considering that the welfare of public schools and public universities are intertwined, individuals from both of these institutions need to have a certain level of ownership in the design and implementation of programs. However, university faculty are uniquely positioned to facilitate these partnerships in ways that present K-12 students with increased access to university resources (Kellogg Commission, 2000). In the sciences this is particularly

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important since many urban secondary schools have limited research capabilities.

A university's commitment to the K-12 schools is based on the recognition that these partnerships can a) improve public relations and the local community's awareness of science, b) increase a university's competitiveness for grants, and c) provide a natural avenue for undergraduate and graduate recruitment in the sciences (Harnik and Ross, 2003; Thompson et al., 2002). When universities adjust and create policies that support K-12 partnerships, structures can be put in place that can be used to develop and support sustainable and scalable programs (Fishman and Krajcik, 2003; Smylie and Weaver-Hart, 1999).

The science mentoring model used in this partnership was based on cooperative learning methods that have specific guidelines and expected behaviors (D. Johnson and Johnson, 1999; J. Johnson and Johnson, 1987; Webb and Farivar, 1994). Cracolice and Deming (2001) consolidate the guidelines specific to peer-mentoring programs into six critical components:

1. The organizations involved in the project need to promote learning, taking into consideration the limits of group size, space, time, and teaching resources.
2. The curriculum materials need to support active learning, work well with groups, and should be appropriately challenging and integrated with the course.
3. The peer mentors need to be well trained and closely supervised.
4. Teachers need to work regularly with peer mentors.
5. The mentoring program should coordinate the curriculum and activities
6. The school must support the program.

Cooperative learning methods, which include peer-led mentoring, have been shown to socialize students, boost achievement, and foster success for underrepresented ethnic minorities in classrooms (Alexander et al., 1997; J. Johnson and Johnson, 1987; National Research Council, 1999; Springer et al., 1999). Peer-led mentoring shifts teaching strategies away from lecture, rote memorization, and telling students what to think, and toward student interaction, active learning, and allowing students to develop their own conceptions (Cracolice and Deming, 2001). "What a child can perform today with assistance she will be able to perform tomorrow independently, thus preparing her for entry into a new and more demanding collaboration" (Bransford et al., 2002, p. 81).

PROGRAM DESCRIPTION

For more than two years, a university-based team consisting of scientists and science educators and secondary science teachers worked together to implement and study a three-tiered program that charged 11th and 12th graders from a large urban school district with the responsibility of serving as earth science mentors for 7th graders from a local feeder school. This paper focuses on Year 2 of this program.

K-12 administrators, school counselors, and teachers were mindful to select mentors and classes of mentees that were representative of their diverse school populations. The participating school district contained above a 75% non-white student population, with more than 80% of all students on free or reduced lunch. During Year 2, a class consisting of 27 randomly selected 7th grade students from a magnet program was scheduled by the participating middle school principal. Twelve 11th and 12th grade mentors were selected based on their academic backgrounds and leadership qualities. It should also be noted that the mentors were academically unique in that they were all on schedule to graduate from a school with a graduation rate of less than 50%.

Within this district, curriculum pacing guides required approximately 10 weeks of earth science instruction during both 7th and 8th grade science. So, for the participating 7th graders, this alternative format provided an additional 5 weeks of earth science instruction. For the 11th and 12th graders, this was an unusual opportunity, considering that the most recent earth science coursework that college-bound high school students in this district would experience occurs in 7th and 8th grade: In fact, the cooperating high school principal created a section of 11th and 12th grade Environmental Science specifically for this program.

During *Tier I*, a three-month training period, the twelve 11th and 12th graders worked closely with the university-based team (consisted of earth scientists, science educators, and secondary science teachers) to learn a tested curriculum on climate science as they prepared to be mentors. In groups, these students a) explored and developed conceptual understandings of particular climate science topics, b) identified and explained these concepts to other team members, and c) developed a mentoring plan around their specific topic. All of the eligible mentors who had participated in the Year 1 program were invited to participate in the Year 2 program. Each of the seven returning mentors was reassigned to a new group and a new climate science topic.

During *Tier II*, the 11th and 12th grade mentors visited a feeder middle school approximately three times a week for five weeks to facilitate a unit on climate science for their 7th grade mentees. On the two 'off' days of each week, the high school science teacher with the support of other members from the university-based team worked with the 11th and 12th grade students as they reflected on and adjusted their mentoring strategies. Each high school student mentored approximately three 7th graders. These small group dynamics allowed the mentor/mentee teams to engage in the cooperative learning strategies modeled during the Tier 1 training, and protected the mentors from management issues common in larger groups (Cracolice and Deming, 2001; D. Johnson and Johnson, 1999; J. Johnson and Johnson, 1987).

During *Tier III*, the 11th and 12th grade mentors worked with their 7th grade mentees to prepare and present a traveling exhibit, or a "road show," to approximately 450 middle school students per year. Originally it had been proposed that participants in this

TABLE 1. CORRESPONDING MENTOR QUESTIONNAIRE AND MENTEE PRE/POST TEST ITEMS ON CLIMATE SCIENCE

Item	Items on Mentor's Questionnaire	Items on Mentees Pre/Post Tests
1*	Describe 2 natural and 2 human-induced factors that cause climate to change	Same
2*	Describe at least 4 impacts of worldwide climate change	Same
3*	With regards to climate change, why can scientists only give a range to future predictions (i.e. temperature, rainfall) instead of an absolute answer? What effect does this uncertainty have on policy-makers and the general public?	Same
4*	List 3 things that you can do (as an individual) to reduce your own greenhouse gas emissions.	Same
5	Briefly explain two things scientists have learned from ice core records such as the one shown. Use specific information from the graph to support your answer.	What evidence do we have that climate change is currently occurring?
6	Describe how ocean sediments, lake sediments, and ice sheets can be used as records of past climate.	What evidence do we have that climate change has occurred in the past?
7*	How do scientists predict that [this state] will be impacted by climate change over the next century?	What evidence do we have that climate change will continue to occur in the future?

*Items on which the mentees experienced significant gains on the post test

road show, like the mentors and mentees in Tiers I and II, would assume the role of climatologist and make observations, collect data, and conduct analyses. However, due to transportation issues and district testing requirements, only a 20-minute visit to each classroom could be scheduled. It was therefore determined that a more realistic use of this time would be for the mentor-mentee teams to create and present a poster that provided an overview of what they had learned about climate science during this program. For this reason, the main emphasis of Tier III shifted to simply charge the mentor-mentee teams with the responsibility of articulating their understandings of climate science to their peers.

Given the limited time span and scheduling constraints of this program, the curriculum employed an *Earth System and Interaction Approach* (Hocking et al., 2006; National Research Council, 1996), which was selected so that the university-based team could better support the 11th and 12th grade students as they explored both climate science and the mentoring process. The university-based team further updated the middle school GEMS Climate Change curriculum (Hocking et al., 2006) to be more developmentally appropriate for the 11th and 12th grade students as they trained to become mentors: The mentors' training materials included up-to-date data sets and news-media and scientific journal articles. The training materials also included a series of templates designed to help the mentors identify the big ideas of this climate science curriculum and to assist them in developing mentoring strategies.

During Year 1, an initial analysis revealed that a) prior to participation in this program, 11th and 12th grade students' conceptual frameworks were limited in scope but relatively intact, and b) that they developed progressively deeper understandings of climate science as a function of their participation in this program, particularly around concepts directly related to human activities (Schuster et al., 2008). A more detailed overview of mentors' understandings of climate science as a function of their participation in the Year 1 program is also available (Schuster et al., 2008).

METHODS OF STUDY

Multiple data collection techniques, including pre/post questionnaires, interviews and examples of students' work, were employed so that we would be able to quantify and describe the a) mentors' and mentees' understandings of climate science as a function of their participation in the Year 2 program, b) characteristics of effective mentoring relationships, and c) scalable and sustainable aspects of this program.

Questionnaire and Interview

Using a test-bank that had been developed by the participating geoscientists to assess non majors' understandings of climate science in an introductory college-level earth science course, a questionnaire was developed to assess mentors' and mentees' understandings of specific climate science topics (Table 1 and Table 2). The mentors' questionnaire was administered one week prior to the beginning of Tier II. Similar to the concept mapping exercise used to assess mentors' understandings of climate science during Year 1 (Schuster et al., 2008) the mentors were given the opportunity to verbally elaborate on their questionnaire responses during an audio-recorded interview. Due to time constrains, the mentees were administered a shorter open-ended pre/post test at the beginning and end of Tier 2, on "off days" when the mentors were not present. This

TABLE 2. OPEN-ENDED ITEMS ON MENTORS' QUESTIONNAIRE NOT INCLUDED ON MENTEES' PRE/POST TEST

Item	Item
A	What is the IPCC and what does this group do?
B	What is a proxy and how are they used to study climate change? Use specific examples in your answer.
C	How could the United States become viewed as a world leader in reducing greenhouse gas emissions?
D	What areas will be most affected by sea level changes in the future?

pre/post test was developed using the mentors' questionnaire: Items 1-4 remained identical (Table 1), items 5-7 were simplified (Table 1), and four open-ended items (Table 2) were omitted from the mentees' questionnaire.

Field Observations

University-based team members made field observations throughout Tier 2. Data gathered during field observations included attendance records, seating charts, and notes on mentor and mentee interactions. As a secondary data source, these field observations were used to help clarify mentor and mentee questions.

Focus Group Interview and Questionnaire for Team Members

Prior to the commencement of Year 2 of this program, six members of the university-based team (four university faculty and two secondary school faculty) participated in a focus group interview. Based on the analysis of this interview, a follow-up questionnaire was developed to evaluate if the team members held similar perspectives after the end of Year 2. The survey was distributed and the results compiled by a third party (Table 3). Similar to the focus group interview, five university faculty and two secondary school faculty completed the survey. Unlike the focus group interview, individual responses were not available or disclosed to the other participants.

ANALYSIS

For the participating mentor/mentee teams, there was a 69% overlap rate, indicating that on average mentors and/or participating mentees were collectively absent approximately four times over the course of this five week --15 session--mentoring program (Table 4). Each mentor's questionnaire with accompanying interview transcript was compiled, transcribed, and any identifiers were removed. At end of the Tier 1 training, an expert panel consisting of three university faculty, whose research and/or teaching focus on the earth sciences, used a four-point Likert scale to quantitatively describe the "accuracy" (0 = scientifically inaccurate to 3 = scientifically accurate) and "relevance" (0 = inconsistent with the scientific literature to 3 = consistent with the scientific literature) of each mentor's written materials (Table 4).

All of the corresponding items from the mentors' and mentees' transcribed responses to the questionnaire (Table 1) were also individually ranked for "accuracy." For example, a mentor's response to Item 1 that was ranked as "scientifically accurate" (a "3") by the entire panel is, "natural factors that induce climate change [are] volcanic eruptions and natural production of CO_2. Some human induced factors are the burning of fossil fuels and cut [ting] down trees or clear cutting/burning forests." A mentor response that was rated as a "1" by the entire panel is, "Natural = volcanic activity [and] polar shifts. Manmade = [blank]."

After rating the corresponding items for all the mentors and mentees, the expert panel convened to discuss their decisions. Based on these interactions, individual panel members could change their initial responses. These collective ratings are used to quantitatively describe the mentors' subject matter knowledge of particular climate science topics (Table 5). In addition, using a matched pair design, independent t-tests were used to analyze 7th grade mentees' (n=12) pre/post test gains with a 95% confidence interval (Table 6). The entire class of 7th grade students (n=25) was able to participate in the mentoring program because it took place during a regularly scheduled class under the direction of the regularly scheduled teacher. However, even after numerous reminders, only 12 parental consent forms, which were required for us to study mentees' class work and assessments, were returned. Unlike the mentees, in order for the mentors to participate in the summer program and aspects of the project that took place outside of their regularly scheduled class, parental or guardian consent was required before these 11th and 12th grade students could be admitted into the program.

At the end of Year 1, the university-based team members participated in a focus group interview. During this interview a consensus building discussion (based on Hill et al., 1997) was used to identify "scalable and sustainable" aspects of the program (Fishman and Krajcik, 2003).

RESULTS

Mentors' and Mentees' Understandings of Climate Science

Mentors' Understandings–Individual Items - Collectively, the mentors were ranked as "scientifically accurate" (> 2.0 on the 0 to 3 scale) on their responses to items that required them a) to describe impacts of worldwide climate change (Item 2) and b) to list things individuals can do to reduce greenhouse gas emissions (Item 4). The mentors were ranked as "scientifically inaccurate" (< 1.0 on the 0 to 3 scale) on their response to item 7, which related to how scientists predict that climate change will impact the future condition of the state where this study took place. On all other item responses (1, 3, 5, and 6), the mentors were rated somewhere between a "1" and a "2."

Individual Mentors' Overall Understandings–

TABLE 3. YEAR 2 FOLLOW-UP QUESTIONNAIRE ON SCALABLE AND SUSTAINABLE COMPONENTS OF TIERED MENTORING PROGRAM

Item	Not at all Important	Somewhat Important	Important	Very Important	N/A
Skilled and experienced teachers and administrators who can overcome challenges that are common in urban schools	0.0% (0)[1]	14.2% (1)	14.2% (1)	71.6% (5)	0.0% (0)
Technical support that allows for synchronous or asynchronous communication between all participants	0.0% (0)	14.2% (1)	28.4% (2)	57.4% (4)	0.0% (0)
Supportive school contexts where transportation issues are manageable.	0.0% (0)	0.0% (0)	14.2% (1)	85.8% (6)	0.0% (0)
Supportive school contexts where class scheduling issues are manageable	0.0% (0)	0.0% (0)	14.2% (1)	85.8% (6)	0.0% (0)
Universities/school districts providing time and salary support for faculty involved in K-16 partnerships.	0.0% (0)	0.0% (0)	28.4% (2)	71.6% (5)	0.0% (0)

[1]Respondents consisted of 5 University Faculty and 2 Public School Science Teachers; Numbers in parentheses represent numbers of respondents per response category.

Questionnaire and Interview Transcript - Five of the seven returning mentors' questionnaire and interview transcripts were rated as "scientifically accurate" ($\geq$ 2.0 on the 0 to 3 scale). One of the new mentors' questionnaire and interview transcript was rated as "scientifically accurate." The returning mentors' average "accuracy" rating was 2.1, which was 0.8 higher than the new mentors' average "accuracy" (Table 4).

Four of the seven returning mentors' questionnaire and interview transcripts were rated as "scientifically relevant" ($\geq$ 2.0 on the 0 to 3 scale). Two of the new mentors' questionnaire and interview transcripts were rated as "scientifically relevant" (Table 4). The returning mentors' average "relevance" rating was 2.0, which was 0.3 higher than the new mentors' average "relevance" (Table 4).

Mentees' Understandings

Mentees post-test scores on the overall paired sample test and on five individual items were notably higher ($p > .05$) than the pre-test. Mentees were rated higher on the open-ended post test items that corresponded with the following topics: a) human and natural induced factors of climate change (Item 1), b) impacts of worldwide climate change (Item 2), c) scientists' abilities to make accurate predictions about future climate conditions (Item 3), d) individual ways to reduce greenhouse gas emissions (Item 4), and e) evidence that climate change will occur in the future (Item 7). Mentees did not make significant gains in their ability to provide evidence on how climate change had occurred in the past (Item 5) and is occurring at present (Item 6).

Characteristics of Effective Mentoring

Coupled with the post test gains, other descriptive measures (Table 4) and field observations were used to identify attributes of effective mentoring. Of the six mentees with above average gains on the mean pre/post difference (> .59), three worked consistently with new mentor N1 and two worked consistently with returning mentor R1. Both of these mentors were rated as having the highest average "accuracy" in their respective groups (new (N) and returning (R) mentors). The other mentee with above average gains on the mean pre/post difference worked with the new mentor N5, who interestingly had the lowest overall average accuracy.

Even though these descriptive measures indicate that these three mentors' content knowledge varied, field observations revealed that they shared several common mentoring traits: First and foremost, members of the university-based team commented that these three mentors excelled at engaging their 7th grade mentees, meaning that they were able to regularly facilitate interactions that related to the assigned science topics. Many of the other groups tended to get off track and discuss other topics not related to climate science. Second, these mentors were described as exceptionally conscientious and consistent, as demonstrated through their ability to systematically work through the curriculum with their mentees, generate substantive artifacts, and by their above-average attendance.

Conversely, three of the returning mentors (R4, R5, and R2) with relatively high average "accuracy" ratings did not consistently demonstrate these same characteristics: Their mentees experienced below average gains on the pre/post test and their groups had difficulty generating substantive artifacts.

DISCUSSION

Before the items on the questionnaire had been analyzed, all 12 Year 2 mentors "agreed" or "strongly agreed" with the statement, "The program helped me better understand the science of climate change," suggesting that all the mentors perceived themselves as having gained a better understanding of the topic as a function of their participation in this program. Even though two-years of participation in this program appears to have had a overall positive impact on returning

TABLE 4. CONNECTIONS BETWEEN MENTOR AND MENTEE PERFORMANCE

HS Mentors (N=New and R=Returning)	Attendance Overlap (%) of Mentors and Mentees	Individual Mentees' Pre/Post Test Gain[1]	Mentors' Accuracy Average[2] and SD[3]	Mentors' Relevance Average[4] and SD
N1	83	0.7 1.0 0.7	2.0, 1.0	2.3, .6
N2	58		1.3, .6	2.0, 1.0
N3	67	0.1 0.2	1.3, .6	1.7, .6
N4	83	0.5	1.0, 1.0	1.3, .6
N5	75	0.9	0.7, .6	1.3, .6
New Average	73	0.6	1.3, .8	1.7, .7
R1	75	1.0	2.7, .6	2.7, .6
R2	67	0.5	2.7, .6	2.0, 0.0
R3	25		2.3, .6	2.0, 1.0
R4	83	0.2	2.0, 1.0	2.3, .6
R5	83	0.2	2.0, 0.0	1.7, .6
R6	83		1.7, .6	1.3, .6
R7	50		1.3, .6	1.7, .6
Returning Ave.	67	0.5	2.1, .6	2.0, .7
Overall Ave.	69	0.59	1.8, .8	1.9, .7

[1]In the cells of this column separate mentee gain scores are provided for each mentee with parental consent. This excludes mentees without parental consent, thus cells have varying numbers of mentees and some cells are empty. Gain scores are derived from a 4-point scale; 0 represents scientifically inaccurate and 3 represents scientifically accurate.
[2]Mentors' Accuracy Average is derived from a 4-point scale; 0 represents scientifically inaccurate and 3 represents scientifically accurate.
[3]Standard Deviation
[4]Mentors' Relevance Average is derived from a 4-point scale; 0 represents inconsistent with the scientific literature and 3 represents consistent with the scientific literature.

mentors' understandings of climate science, the additional experience did not appear to improve their abilities to be more effective mentors. Due to the limited number of mentors and mentees, it is difficult to definitively explain the reasoning behind this observation. Still, some members of the university-based team perceived that the new mentors were more excited and willing to engage in the formal mentoring component (Tier 2) of this program than the returning mentors.

Considering that the reliability of the metrics administered to the students is unknown, some of the variance in mentors' and mentees' responses might be a function of item difficulty, and not solely representative of differences in students' understandings of climate science. Even though the mentors' Tier 1 training modeled and emphasized the importance of developing evidence-based explanations, the mentors and their mentees still did not perform as well on the items that required detailed explanations. Even though the intensive Tier 1 training was designed to teach the mentors how to interpret paleontological data, none of the mentors were able to develop "accurate evidence-based explanations for Item 5 or Item 6. The mentors received lower ratings on the items (including Item 5 and Item 6) that required evidence-based explanations. These were the only two items without significant gains on the mentee post test.

Initially it had been proposed that the mentors would be selected from a science magnet school whose graduates

TABLE 5. MENTOR RATINGS ON QUESTIONNAIRE ITEMS THAT CORRESPOND WITH MENTEE PRE/POST TEST

Item #	1	2	3	4	5	6	7
Item Ave[1]; SD[2] (n=12)	1.8, 0.6	2.3, 0.4	1.2, 0.3	2.8, 0.3	1.1, 0.4	1.3, 0.5	0.6, 0.2

[1]Item Average derived from a 4-point scale; 0 represents scientifically inaccurate and 3 represents scientifically accurate. Each Item is listed in Table 1.
[2]Standard Deviation

TABLE 6. DIFFERENCES ON MENTEE PRE/POST TEST CLIMATE SCIENCE ITEMS

		Mean Difference; SD[1] (n=12)	t-value	p-value
Item 1*	Post1 - Pre1	.61, .70	2.883	.016
Item 2*	Post2 – Pre2	1.27, .73	5.814	.000
Item 3*	Post3 – Pre3	.27, .33	2.761	.020
Item 4*	Post4 – Pre4	1.24, .87	4.727	.001
Item 5	Post5 – Pre5	-.06, .76	-.263	.798
Item 6	Post6 – Pre6	.24, .42	1.901	.087
Item 7*	Post7 – Pre7	.54, .64	2.828	.018
Overall*	Post Ave-PreAve	.59, .33	5.952	.000

*Items on which the mentees experienced significant gains on the post test
[1]Standard Deviation

usually pursue science as a major in college. The expectation was that the magnet students would have prerequisite knowledge in science and mathematics that would support them as they a) engaged in climate science and b) trained to be mentors. However, due to scheduling difficulties at the science magnet, the district reassigned this program to another small school with a language emphasis. It was communicated to the university-based team that the science magnet students had fuller schedules and therefore it would be more difficult for them to participate in this program.

During Year 1, the participating mentors struggled with graphing, analyzing, and interpreting data. At the end of Year 1, the curriculum was modified to provide additional opportunities for the university-based team members to work with the mentors in these areas. After the second year it became evident that prerequisite mathematics and science course work would have greatly benefitted the mentors as they attempted to understand and model the climate science curriculum.

Beyond the Mentors Participation in this Program

In response to a survey that was distributed and compiled by a third party, all 12 *returning and new* mentors "agreed" or "strongly agreed" with the statements, a) "I enjoyed participating in [this] program," b) "I would recommend [this] program to my friends," and c) "I [felt] prepared to mentor 7th grade students on the topic of climate change." Ten of the twelve students also "agreed" or "strongly agreed" that the program helped improve their public speaking confidence.

To further support these promising students as they prepared to leave this program, a high school guidance counselor and university advisors were invited to meet with the mentors for three counseling sessions. The goal of these sessions was to address questions that the mentors had about applying to college. At the completion of these sessions, all 12 mentors indicated that they planned on going to college. Five out of the twelve mentors indicated that they were planning on choosing a science major in college. All 12 mentors "agreed" or "strongly agreed" that "the program introduced me to careers in the geosciences" and all but one student "agreed" or "strongly agreed" that "what [they] had learned in this program [informed their current] college and career plans."

At the end of their school year, all nine of the 12th grade mentors had applied to college and seven had been accepted to one or more colleges. Of the seven who had been accepted to college, three indicated that they were considering majoring in science.

Recognizing that the students selected for this program did not necessarily gravitate towards the sciences, the program appears to have improved the students' awareness of the earth sciences and careers in the geosciences: If students desired to pursue science as a career, this partnership had the capacity to help prepare them to be scientists. If students were still not interested in pursuing science as a career after participating in the program, the partnership attempted to create informed citizens who are able to understand what is presented in the news media and by scientists.

Sustainable and Scalable Aspects of the Mentoring Program

Participants of the focus group interview identified four "sustainable and scalable" (Fishman and Krajcik, 2003) aspects of the program, including (a) choosing supportive school contexts where transportation and scheduling issues are surmountable, (b) working with skilled and experienced teachers and administrators who are able to overcome challenges that are common in large inner-city schools, (c) increasing technical support to provide opportunities for synchronous or asynchronous communication between all participants, and (d) recognizing the importance of universities providing time and salary support to sustain K–16 partnerships. As indicated by Table 3, there was a general consensus that the Year 1 recommendations for developing a sustainable and scalable tiered mentoring program were still applicable after Year 2.

Choosing Supportive School Contexts

Boyd, Kerchner, and Blyth (2008) observe that alignment of district programs and resources must occur before programs in urban schools become sustainable. The support of the central office was essential. For example, establishing this mentoring program within the parameters of a regular school day required a shared bell schedule and an aligned curriculum between the high

[3]It was communicated to the university-based team that the science magnet students had fuller schedules and therefore it would be more difficult for them to participate in this program.

school and middle school classes. Similarly, if a larger study was going to take place, it would become necessary for the central office to ensure that all parents and guardians would receive and had the means to return consent forms.

Over the two years that this program was implemented, broader organizational changes were also occurring in the school district that had the potential to impact or even undermine this partnership. For example, between Year 1 and Year 2 the participating schools were restructured and all participating administrators changed schools. These unexpected adjustments required consideration of how the program could be adapted to value new participants' ideas while still promoting the original goals of the program (Hargreaves, 1994).

Working with Skilled and Experienced Teachers and School Administrators

Teachers' and school administrators' willingness and ability to assume ownership allowed the program to adapt to the changing circumstances experienced in the district. Specifically, the teachers and their administrators worked together to overcome obstacles and to champion the program. Songer, Lee, and McDonald's (2003) description of "maverick" teachers corresponds to what we observed in our volunteer participants. The volunteer teachers and school principals were able to transcend circumstances common in inner city classrooms that make it difficult to implement certain aspects of science instruction (Bransford et al., 2002; Songer et al., 2003, p. 491; White and Frederiksen, 1998). Programs that are implemented with skilled and experienced teachers and administrators are more likely to support innovative science instruction.

Synchronous or Asynchronous Communication

Synchronous or asynchronous communication via interactive classroom management systems has the potential to provide secondary science teachers and students with ongoing access to scientists during the school-year portion of university-K-12 partnerships. Open source "learning management systems" (LMS), such as Moodle, can be designed to regularly prompt students to explain their current understandings and record their responses, and these responses can be simultaneously reviewed and scaffolded by their teachers. Research scientists can address teachers and/or students' questions in real time (synchronous) or respond within 24 hours (asynchronous). Furthermore, scientists can commit to manageable periods of time without having to physically leave their research program or abruptly change their schedules.

University Support of Faculty

These recommendations for developing sustainable and scalable programs were partially based on the recognition that it is extremely time intensive for university faculty to participate in K-12 partnerships. Outreach is often considered outside the realm of defined scholarship and participation can threaten tenure and promotion (Thompson et al., 2002): The members of the university-based team from the school of science included one full professor and two clinical instructors, but no assistant or associate professors.

Furthermore, because university-K-12 partnerships do not focus on university students, they are often viewed as outside of the primary job responsibility of university faculty. If education faculty desire to facilitate and study mentoring programs, regular visits to the classroom during the academic year become essential. For this reason, this form of scholarship and outreach needs to be recognized, valued, and supported by universities.

CONCLUSION

Traditional K-12 public school science instruction is remarkably resilient to change (DeBoer, 1991; Rudolph, 2000). When meaningful partnerships between scientists and science educators are developed and sustained, innovative programs have the potential to both transcend the "pedagogy of poverty" and further geosciences education in K-12 settings. When university faculty, secondary teachers, and administrators receive ongoing support from their respective institutions, there is the potential for students to become more actively engaged as science learners. However, if meaningful partnerships are to be developed and sustained, school district and university leadership need to collectively recognize, prioritize, and commit to the amount of time, resources, and human capital that will be required to transform existing programs.

Within this tiered-mentoring program, students were supported by science educators and climate scientists. As the mentors and mentees explored current data sets and research articles and conducted related labs and activities, they had to be mindful of how they would eventually interact with their younger peers. Learners were not disconnected from the norms of scientific practice, but experienced a heightened level of accountability and authenticity. As students become a part of a broader community of geoscientists, there are increased opportunities for them to develop a) cogent conceptual frameworks around various earth science topics, and b) a more accurate understanding of climate science research.

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