Developing Scientist Educators: Analysis of Integrating K-12 Pedagogy and Partnership Experiences into Graduate Science Training

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INTRODUCTION

Collaborations between members of the scientific community and K-12 educators are increasingly seen as a key mechanism of science education reform in the United States (Alberts 1993; Alberts, 1994; Bower; Bybee, 1998; NRC, 1996; NRC, 2002; Schultz). Although these scientist-teacher partnership approaches have been emerging over the course of two decades, there is an increasing attention to and funding of these efforts. In 1999, the National Science Foundation (NSF) founded the GK-12 Fellowship Program, which makes awards to university science-based faculty to engage graduate students in partnerships with local K-12 teachers as part of their graduate training. Over its short history, the NSF GK-12 Program has funded over 167 projects and integrated K-12 science education experiences into the training of over 5000 graduate student scientists (NSFa; S. Ortega, personal communication). In addition, the 2001 NSF Mathematics and Science Partnership Initiative which made over 500 million dollars available to facilitate reform of K-12 math and science education (NSFb). The potential benefits for the K-12 educational system are enormous, including scientist role models for students, increased knowledge of scientific concepts and experimental approaches for teachers, and the integration of scientific inquiry experiences into K-12 science teaching and learning. But what, if anything, do participating members of the scientific community themselves learn from collaborating with K-12 teachers and students? The majority of science professionals involved in scientist-teacher partnerships are scientific trainees (e.g. graduate students, postdoctoral fellows), many of whom will go on to teach at colleges and universities and do so with little or no formal pedagogical training. As such, partnerships have been more recently proffered as an innovative approach that could stimulate a change in the training of future scientists and a reform of undergraduate science instruction.

That said, science education partnership as a discipline is both understudied and under-theorized. While there are a variety of guiding publications that offer insights into challenges and successes associated with partnerships (Caton, 2000; Dolan, 2004; McKeown, 2003; Moreno, 1999; Munn, 1999; Pelaez, 2002; Sussman, 1993; Tanner, 2003), there are few research publications that investigate the impact of these efforts on participating teachers, students, and scientific professionals (Bruce, 1997; Gilmer, 2005, Phillips, 2002; Tanner, 2000; Thompson, 2002). In 2004, the Science Education Partnership and Assessment Laboratory (SEPAL) at San Francisco State University (SFSU) sought to extend previous research specifically on the impact of partnerships on scientists and began examining the impact of formally integrating K-12 partnership experiences into the training of graduate students. The SEPAL GK-12 Partnership Program, supported by funding from the NSF, engages SFSU Master's science students in year-long, time-intensive (10 hours per week), one-on-one partnerships with secondary science teachers, simultaneous with a two-semester, 2-hour weekly seminar course in science education, pedagogy, and partnership. The course is designed to give GK-12 Scientists an introduction to basic pedagogy, including the use of a variety of teaching styles, classroom assessment, inquiry-based teaching, and lesson planning and debriefing strategies. The course also provides structured opportunities for scientists to learn from each other by using various case study and group discussion formats to address challenges they face in their classroom and practice communicating science to K-12 students. Specifically, each scientist is charged to create a hands-on, age-appropriate lesson that communicates their research to their students. Scientists work together to translate their research into kid-friendly, easily communicated language , called *First Translations,* and give each other supportive ideas and feedback in designing their research activity, or *GK-12 Research Lesson*. In addition to the weekly seminar for the scientists, the GK-12 program provides a monthly workshop for the entire community of GK-12 Scientists and Partner Teachers. These workshops are primarily participant driven, allowing partner teams to discuss what has been successful and what has been challenging in their classrooms. Each partnership team is given an opportunity to present a case study on a science lesson (formally called a *GK-12 Lesson Study*) they have co-taught. These *GK-12 Lesson Studies* provide opportunities for each team to showcase what they have collaborated on, work together on thinking about how to employ novel teaching strategies, and gain valuable insights about science teaching and learning from their GK-12 colleagues.

This study began to address several questions around whether the integration of a formalized K-12 science education partnership experience as part of their graduate experience influenced participating scientists' professional identities. We were interested in examining to what extent scientists begin to think about themselves as both scientists and educators. In particular, what do Master's-level scientific trainees <u>themselves identify</u> as key learnings from partnership experiences? To what extent do reported outcomes vary among individuals within a cohort? In what ways, do partnership experiences influence the professional identities of these scientific trainees? Finally, what evidence is there that newfound pedagogical knowledge may impact scientists' future teaching endeavors, especially at the undergraduate level?

METHODS

To assess the impact of classroom partnership experiences and changes in scientists' attitudes toward teaching science and their professional identity, a variety of assessment and evaluation probes were piloted with the 2004-05 cohort of GK-12 Scientists. For this paper we have limited our analysis to a collection of final, summative, reflective essays, submitted by participating scientists (n = 10) at the commencement of their GK-12 experience. Scientist participants were given the question: "What have you learned from your GK-12 experiences this year that will continue to influence you for many years to come? How did you learn these things?" Scientists' reflections were all greater than 600 words, with the range being 628 words to 1955 words. Analysis of these reflective essays included multiple readings of individual essays, which allowed authors to identify emergent themes that were common across individuals. The authors identified five major themes in the essays, with each theme containing multiple categories. In all, 13 categories of responses were identified (see Figure 1 and Figure 7). The authors subsequently extracted sections of text (quotes) from each individual's essay and assigned them to one of the categories. In some instances, quotes fit into more than one category. Through this process of extracting quotes and categorizing them, 62% of total qualitative data (all quotes from all scientists), are represented within these 13 categories.

Analysis of the remaining 38% of scientists' reflections revealed that the remaining text consisted primarily of classroom anecdotes, background descriptions, and outcomes that were specific to individual scientists and their partnerships. To assure inter-observer reliability and reproducibility, all quotes that had previously been assigned a category were randomized and re-scored against a blank matrix containing the 13 categories by two additional science education research assistants and this paper's primary author. In general, there was agreement across observers in most of the 13 categories.

RESULTS

Analysis of reflective essays from GK-12 scientists reveals they experienced professional gains and insights in a variety of ways. Different participants chose to report different aspects of their learning due to the open-ended nature of the question posed on the final reflective essay. This was expected and desirable to allow for the diversity of themes that could emerge from participants. The majority of benefits that scientists noted fall in to five overarching themes (see Figure 1), which contain the 13 categories. These themes included: 1) Communication Skills, 2) K-12 Insights, 3) Partnership Insights, 4) Pedagogical Skills, and 5) Professional Identity Shifts (see Figure 1). Post-hoc quantitation of categories revealed robustness across the cohort of scientists within each category. In addition, post-hoc quantitation across categories for each participant revealed that scientists reported a varied distribution of learning experiences.

Theme 1: Communication Skills: Many scientists reported improved communication as being one of the direct benefits of partnership. Scientists discussed how this improved communication will facilitate their interactions with other science professionals, as well as non-scientists in the future. For some scientists, this included an appreciation for use of appropriate language, while for others it was a new awareness of connecting with the vast world of people outside scientific research. The two distinct categories that fell out of the Communication Skills theme were: A) communicating their research and B) A) increased value of and improved communication (see Figure 2).

Communicating their Research: *Scientists improved their ability to talk about their Master's research with K-12 students, other scientists outside of their discipline, and the lay public.*

> *Scientist L*
> "I think a big skill I have gained and come to appreciate is the use of appropriate language to explain my research to others outside my field of biology and outside the realm of science… This awareness of the people outside of my research and the need to create a common understanding with them is one of the most precious things I think I have gained this year."
>
> *Scientist O*
> "The first thing that comes to mind when I think about what GK-12 experiences will continue to influence me for years to come is the development of our research lessons. It is one thing to struggle with putting together a lesson about a concept that is outlined in a textbook, and quite another to develop a lesson pertaining to one's own research. I do think this is something every scientist should know how to do. I really appreciated the environment in which we discussed our research

and lesson plans with each other. As each one of us struggled to understand what everyone else was doing, it was easy to ask questions and admit we do not know everything about science."

Scientist I
"Many of the concepts that I have learned as a graduate student are quite complex. The GK-12 program has forced me to learn how to communicate these ideas using simple language. Just the other day, a professor in an unrelated field asked me what I'm studying. I was able to describe my thesis in three simple sentences. And about five minutes ago, my landlady knocked on the door. In the course of our conversation I explained my thesis to her – and she's a sales manager for Coors! There are two primary ways in which the GK-12 program has promoted this: through the research lessons and through our "first translation" for students which we then discussed with other scientists in our seminar."

Increased Value of and Improved Communication: *Scientists reported improvements in their communication and public speaking skills, and also addressed an increase in how much they value good communication.*

Scientist N
"One of the most important skills I improved upon this year is my ability to speak clearly and concisely to others. Communication is a critical component of nearly every profession. Finding simple ways to explain lessons so all students can hear and appreciate what is being said is something I have struggled with in the past."

Scientist J
"I will be able to communicate with [future colleagues] about how we function as a team because I have already had experience forging such relationships."

Scientist I
"The time that I have spent interacting with students one on one or as a class has taught me that I'm a capable public speaker, that I can think on the fly and that I'm able to relate to students."

Scientist L
"I have been more conscious when I talk about my work with others. I realize even people in my *own* lab don't know what I am talking about sometimes as we study different groups of [organisms]. Imagine what a chemistry or physics major may think when I rant off at the mouth about genes and trees and nomenclature?!!? For fear of sounding too general, I think the world is [complicated] because of large misconceptions and miscommunications. In my perspective GK-12 has helped me close that gap (in understanding) a little more."

Theme 2: K-12 Educational System Insights: Scientists reported a variety of insights on the K-12 educational system including: A) K-12 system and schools, B) teachers, and C) students (see Figure 3).

On K-12 System and Schools: *Scientists gained an awareness of issues around the K-12 educational system in general.*

Scientist O

"The struggles public schools face in preparing children for academic and personal success has unfolded before me during the past two years, and my time at [my school site] has really shed some light on a very complex problem. There does not seem to be a working partnership between the administration and the teachers, and this leads to friction in our educational system. I see students who want to take pride in their school, but often get the message that they must go without some very basic necessities, like paper and a photocopier that works. I see teachers that are overworked and underpaid. I see administrators, who try to create and support a successful learning institution, but often fall short and end up doing damage control. Budgets seem to be either severely mismanaged or altogether extremely deficient and do not provide for the basic resources necessary to support teachers who are required to provide an engaging, supportive, stimulating learning environment for a diverse community of learners."

Scientist I

"I see more clearly than ever before how the education system is failing students at every level. This has nothing to do with teachers – they certainly do inhuman amounts of work in incredible difficult situations – but has more to do with how schools are viewed in this (and probably many other) cultures. They've become institutions of memorization rather than institutions of learning. Through these realizations and the articulation of my teaching philosophy, I'm able to see where I could make a difference."

Scientist Q

"I learned that students entering the university system might be lacking in basic understanding of science concepts and principles. I will draw on my experience "in the trenches" at [my school site] to have a much better understanding of the state of education today and how effective the system is at preparing students for college. This will then allow me to make adjustments to my own teaching."

On Teachers: *Scientists gleaned a greater understanding of the K-12 teaching profession.*

Scientist L

"It never really registered what a demanding job K-12 teaching could be. I think I really got to experience all the planning and the effort that goes into being a science teacher. All the curriculum development and the administrative details of teaching are enough to fill an eight-hour day, without the actual instruction time."

Scientist Q

"I learned that the dismal performance of many schools is not the fault of the teachers."

Scientist O

"It was interesting to compare scientist and teacher attitudes and methodologies in collecting data that influences how we do our jobs. I came to appreciate the similarities and differences in a new way as I understood them both better."

On Students: *Scientists achieved a better understanding of the way kids learn and improved their ability to relate to K-12 students.*

Scientist K

"I realized that what I wanted and what the students believe they needed were diametrically opposed to each other. However, after many personal talks with the students, I soon discovered that they were not as concerned with the subject matter itself as they were with how the subject matter was being taught. They were more concerned with my attitude and [my partner's] than the answers we would give them. This was a revelation."

Scientist Q

"I learned that students, when given the opportunity to do science, are capable of truly high achievement."

Scientist M

"Maybe it was just my luck, but I learned that students at a "bad" school are neither unintelligent nor unmotivated. Of course, there are some students that would rather be texting their friends; but even these students pay enough attention to the instructors in order to learn what we are trying to teach them. This I learned not from any particular experience, slowly over the course of the entire year. I must say I was intimidated to be working in an inner-city school that had a reputation for "bad" kids. But most of my experiences with the students proved them to be attentive and concerned about their future."

Scientist L

"I have learned you have to share yourself and some of your life with your students in order to engage them in science to demonstrate that science is in their lives everyday… When [my partner] tells the class stories about his family (when discussing genetics) or the trees in his garden (when discussing photosynthesis), the students are truly engaged and we learn so much easier using analogy and real life examples. I have learned to use this method when talking and communicating to others. It is very important to make science familiar to your audience no matter the age group."

Theme 3: Partnership Insights: Working collaboratively with teachers and other scientist participants in the GK-12 program facilitated mutual learning opportunities for scientists. Scientist stated that they: A) learned how to be an effective partner and B) increased how much they value collaboration (see Figure 4).

On Being an Effective Partner: *Scientists discussed how they gained the skill set and desire to create partnerships and collaborations that extend beyond the scope of the scientist-teacher partnership model of the GK-12 Program.*

Scientist J

"In the next 5 years, I will be a partner in several ways. I will be teaching with professors who have their own styles and sets of expectations, both for me and for their students. I will also be a research partner with the scientists leading the labs I'm working in, and with my colleagues in the labs. I anticipate these relationships to be a lot more friendly than business-like, but all prior experience negotiating partnerships will help… I will be able to communicate with [future colleagues] about how we function as a team because I have already had experience forging such relationships."

Scientist P
"One particular challenge that was particularly helpful for my partnership was the lesson study presentation. As a result of this presentation pressure a different sort of conversation took place between my partner and I. Although each week we are asked to debrief and discuss the successes or failures of a lesson in the context of our goals for that lesson, we failed to engage in this conversation often. Having to present a dilemma to our peers however put some pressure on us to consider what we were struggling with verbalize it to our partner. Having these conversations made us partners with a common struggle."

Scientist O
"I certainly understand the value of sharing responsibilities and being able to rely on a working partner in order to succeed in the goal of educating our students and fostering a love of learning."

Increased Value of Collaboration: *Scientists reported not only how much they value the depth of thought and reflection that collaboration allows, but also the practical advantages of working with a partner.*

Scientist K
"I have realized that collaborative reflection can have a greater impact than solitary reflection because others can push me to look deeper and harder; to go places I may not think about or even be willing to think about on my own… I came to understand, especially during our discussion on equity, that when I tell others my story—when I share with others what I did and why, what happened as a result, why I think it happened, and what it might mean—several things take place that do not happen when I process my thoughts alone: (1) I hear my own thoughts aloud along with the verbal inflections and intonations that suggest meaning beyond the words; (2) I tap into mindsets that perceive differently from my own, and therefore are not bound by the shoulds and coulds I might carry as baggage; and (3) I am able to elicit and receive feedback that is informed by experiences, knowledge, and beliefs different from my own and therefore capable of providing new insights."

Scientist L
"I soon realized that teaching really is a team effort and that most successful teachers work as a team or in a group environment. It had made a lasting impression on me to watch all the teachers working together. It is a reminder of the power of collaboration, and I will take it into my own scientific work."

Scientist H
"I am very appreciative that my [teacher partner] is such a willing and capable collaborator. The year would not have been half as good with a teacher unable to share the responsibility of creating hands-on, inquiry-based, [science] lesson plans. Consistently throughout the year we planned fun and enriching activities that, for the most part, have worked well. We also spent a great deal of time evaluating and assessing student learning and participation… Working with [my partner] this year has been highly educational and rewarding."

Theme 4: Pedagogical Skills: Scientists gained a foundation of pedagogical knowledge including insights into issues relating to: A) assessment, B) classroom equity, C) inquiry, and D) lesson planning strategies (see Figure 5).

Assessment: *Scientists gained various tools of student assessment. In the SFSU SEPAL GK-12 Program, assessing student learning is to both to inform instruction by letting student ideas and attitudes guide teaching and in the service of learning by giving students an opportunity to reflect on their own knowledge.*

Scientist H
"I have really enjoyed learning how to develop relevant and cogent questions and then assess how well students learn the material by comparing their responses to their initial statements. Measuring learning in an objective manner is no small task because there is so much room for subjective interpretation. I hope [my teacher partner and I] can structure [next] year so that assessment can be more systematic, routine, and efficient."

Scientist J
"I've learned how to expand my range of questions to elicit the kind of information I'm seeking (open vs. closed-ended)… I've learned how to quickly assess the student's understanding of a lesson and use that to my and their advantage in the next lesson (minute papers)."

Scientist P
"I come away from this project with the conviction that assessment is a useful, illuminating tool that can be used in my own teaching. I look forward to learning more about it in my own teaching."

Scientist Q
"I learned that student assessment involves more than seeing what students learned. I found assessments to be useful as a gauge of how effective a lesson plan was, as a learning tool in itself and as a way to uncover misconceptions."

Scientist N
"The idea of using assessment as a learning tool for the students to understand what they have learned and to use assessment as a tool to gauge what the students have learned, as well as to unveil any misconceptions, will be very useful."

Classroom Equity: *Scientists reported a new awareness of issues related to classroom equity and described practical tools they gained that facilitated their ability to provide more access for student science learning. The SFSU SEPAL GK-12 Program defines equity as creating access for and engaging all students in science learning by promoting active student participation across a diverse set of learning styles and student backgrounds.*

> *Scientist P*
> "What we can do as teachers is to give each student an equal opportunity to participate in science class. I can make sure that each student has materials they can work with, that they are working in a situation where they can participate, I can also keep my hands in my pocket and let the student manipulate objects according to verbal instructions, I can practice waiting after I pose a question so that everyone has a chance to think of the answer, I can say things like 'I want to hear everyone's voice', I can have students have pair-share where they talk to one another before answering to a group, I can also use a whip as a way to hear from everyone in the class in a brief period of time. Using these strategies, there is a better chance for students to learn something regardless of their socioeconomic status. I have learned that socioeconomic status needs to be acknowledged so that inequities are not introduced by assuming that every child understands your perspective."

> *Scientist I*
> "By completing the exercise in which we collected classroom evidence related to equity, I have become much more aware of whom I talk to in the classroom. I now make a point of asking each table at least one question, rather than only responding to students whose hands are raised."

> *Scientist J*
> "Through readings and some discussions during our weekly meeting, I learned more about how working in pairs and small groups can be beneficial for the students. It can help shyer students have a voice in the class, and it can facilitate the student's learning of the material."

> *Scientist H*
> "Part of the challenge of teaching is developing meaningful and accurate questions to ask students, and part of the challenge is creating lessons that will be relevant to all the students – especially ones with limited vocabularies…"

Inquiry: *Scientist gained an understanding of teaching science using an inquiry approach, where students are given opportunities to develop the habits of mind of a scientist and ask questions about the natural world.*

> *Scientist P*
> "Prior to my encounter with the SEPAL GK-12 Partnership Program I was largely unaware of inquiry-based teaching. Participating in this program I have learned that inquiry is a way to engage students and is actually very much a part of science. I learned these things through reading and experiencing inquiry for myself."

Scientist J
"Strangely, I'd never before consciously made the separation between questions we wonder about that are too big to answer, and small questions we can expect to address. That day we talked about how we might break those big questions into tiny bite-sized pieces. I suppose I do this all the time, without realizing it. But I think it's helpful for the beginning science student to be guided through those thoughts."

Scientist K
"I also discovered that, although laboratory exercises can aid in the process of sense-making, they often do not because they are either cookbook where they do not allow the students to make their own choices or judgments, or confirmatory where they follow lectures or reading by students. Therefore, I have realized that the essence of inquiry does not lie in any elaborate, equipment-intensive laboratory exercise, but rather, in the interactions between the student and the materials, as well as in the teacher-student and student-student interactions that occur dozens of times each and every class period."

Scientist H
"One clear theme this year was inquiry. My role in shaping activities and creating unique learning experiences was open-ended, yet vividly outlined by the goals of the GK-12 program. I enjoy structuring activities that follow the scientific method and invite students to solve problems by experimenting."

Lesson Planning Strategies: *Scientists discussed a variety of practical skills around science lesson design and development.*

Scientist I
"Through working with my partner teacher, I have learned how to create a lesson plan that teaches content and process goals, is engaging, and that students will enjoy. At the beginning of the year, I had no idea how to create a lesson plan. Instrumental in me acquiring this skill was the research lesson activity we created during the fall semester. It was great practice to move from brainstorming ideas to implementation of the lesson itself. I was able to see what worked and what didn't work in the classroom."

Scientist J
"On another very practical level, I've learned to create a lesson plan from the original concept to the final assessment."

Scientist Q
"I learned that students will be more engaged in a topic if they spend a few minutes writing about something before a lesson."

Theme 5: Professional Identity Shifts: The most remarkable benefits scientist participants describe relate to how their pedagogy and partnership experiences have significantly impacted their professional identities and expanded their definition of what it means to be a scientist. Two distinct categories comprise this theme: A) role of scientists in K-12 education and B) influence on future teaching practices. Both categories reveal scientists' attitudes about how the their GK-12 experiences will affect their professional future (see Figure 6).

Role for Scientists in K-12 Education: *Scientists realized the value of science professionals' involvement in the K-12 educational system. In addition, working with teachers in a K-12 classroom enabled many scientists to both discover their breadth and depth of science knowledge and see its contributive application.*

> *Scientist I*
> "For the first few months of the program, every week I would be confronted with the question: What did you learn this week in your role as a GK-12 scientist? It was difficult to answer because I had no idea what my role in the classroom was. Though I may still be unclear on exactly what the role should be, I certainly know that there is a role for scientists in K-12 classrooms. This role can take on many forms depending on the teacher, the day, the students, and the activity. Elucidating the possibilities of classroom partnership between scientists and teachers provides me with the confidence to continue working in schools.
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> *Scientist O*
> "The contribution I have made as a result of being part of the GK-12 Program has given me tangible proof that as a scientist I can make a difference in our educational system and it has greatly influenced my desire to do so."
>
> *Scientist I*
> Just as my involvement in this program has enabled me to discover how much I know about science, I have realized how much I have to contribute to a science classroom. I have learned this through my journal entries which have caused me to reflect on what I have to give as well as what I have to learn."

Influence on Future Teaching Practice: *In addition to scientists reporting gaining a foundation of practical teaching strategies and a deeper understanding of K-12 schools, most scientists noted that these pedagogical and partnership gains will impact their future teaching at the undergraduate level.*

> *Scientist Q*
> "The most important thing I learned from participating in this program is that much of what I learned will be useful to my teaching career at the college level. When applying for the GK-12 program, I was concerned that it was meant only for students interested in teaching at the K-12 level. Although it was made clear that that was not a requirement, it was something that I often thought about. Under the instruction of [GK-12 Community Leader], it became clear that much of what we were learning about in the seminar will be applicable to a college-level teaching career."
>
> *Scientist P*
> "Participating in the SEPAL GK-12 Partnership Program I have learned about inquiry based teaching, cooperative learning, equity, equity strategies, the influence of socioeconomic status in a classroom, assessment, co-teaching, and

learning styles. All of these ideas have laid a foundation for my future teaching endeavors and will influence me for years to come."

Scientist I
"Teaching every week and learning about different pedagogical methods has enabled me to articulate my own teaching philosophy. The teaching philosophy writing assignment has been instrumental in this. Through that exercise, I was able to critique my own experiences as both teacher and student… Should I go on to a job as a professor, I have a much better idea about how I would teach. I would love to be a beacon for institutional change one day. That would be such satisfying work!"

Scientist H
"I can say for certain that the GK-12 program has been instrumental in shaping my career. It is the right program with the right instructors and the right co-teacher at the right time."

DISCUSSION

Although there has been a great deal of interest in the influence of science education partnerships on K-12 science education, the data presented here contribute to a growing body of research evidence that begins to address the impact of these partnerships, in particular the impact on participating scientists (Bruce, 1997; Gilmer, 2005, Phillips, 2002; Tanner, 2000; Thompson, 2002). These results extend previous findings and reveal new aspects of outcomes for scientists, which appear to be directly related to inclusion of the partnership experience into the formal training of these scientist participants. In particular, the data presented here include detailed scientist descriptions of pedagogical techniques and their potential applicability to not only the K-12 setting, but also future teaching endeavors including undergraduate settings. As such, formalizing partnership experiences as part of graduate training may be a promising approach to developing young scientists that consider K-20+ science education reform integral to their professional lives as scientists. Analysis of additional data collected for this cohort of scientists is on-going and will further inform the emergent categories defined here. In particular, analysis of scientists pre- and post- statements of teaching philosophy should provide more detailed insight into how scientists' pedagogical stances are changing over the course of their K-12 partnership experiences. In addition to providing insight into the impact of one particular partnership program on participating scientists, the data presented here also raise more global issues and questions about 1) the role of partnership in K-16+ science education reform and the training of future faculty, 2) future avenues of inquiry in building the discipline of science education partnership research.

On the potential of partnership in K-16+ science education reform

Many of the scientific trainees participating in this and other partnership programs nationwide will go on to positions as undergraduate faculty. As such, the integration of partnership and formal pedagogical training into the graduate experiences of these future scientists may contribute to the reform of undergraduate education. In contrast to partnership programs where involvement is voluntary and episodic, the GK-12 Program provides a structured experience in pedagogy and partnership that is integrated into the fabric of a scientists' academic training. However, little is known about the extent to which scientists – such as those in this and previous studies – retain and are able to apply what they have learned from K-12 partnerships in their own professional endeavors. In addition to providing short-term insights into the immediate perceived outcomes of partnership experiences for scientific trainees, we also view this data as baseline data to be used to track the extent to which their own identified learning outcomes from the GK-12 experience continue to influence these scientists as they mature professionally. More specifically, these data, coupled with the other data sources collected such as Statements of Teaching Philosophy, provide a platform from which to examine how these scientists are influenced in their future teaching practice.

On emerging partnership research questions and methodologies

Although the data presented here begin to address the impact of partnerships on participating scientific trainees, it is only a small step towards deepening our understanding of the nature and impact of these collaborations across traditional institutional and disciplinary boundaries. The majority of partnership research questions remain unaddressed. Specifically in the realm of the impact of partnerships on scientific professionals: How do partnership outcomes for scientific trainees vary across different programs? – with the culture of an institution? – with the stage of training of the participating scientific trainee (e.g. Master's level student, doctoral student, or postdoctoral fellow)? What are critical aspects of professional development for scientists concurrent with their partnership experiences that best promote the described learning outcomes? What are the relative impacts on a scientist's pedagogical stance of K-12 partnership and pedagogy experiences versus traditional teaching assistantships? And these are only the beginning of a stream of questions on the impact of partnerships on scientist participants, without yet delving into the influence of these relationships on K-12 teachers, K-12 students, and other stakeholders. In the emerging discipline of science education partnership, we have many more questions than keen insights at this early point in the history of the field.

In addition, the field of partnership is in need of more common research instruments and research methodologies that can be used to examine the relative impact of different partnership approaches in different contexts. For example, many programs have informally shared that partnerships have a positive impact on scientists' communication skills. However, the nuances of what exactly that means – improved communication skills – across different partnership programs remains very unclear. As members of an emerging partnership research community, we are interested in developing a more systematic, common approach across researchers for investigating outcomes of partnerships, not only for scientists, but also for teachers and students. The results of this small study will inform the development of tools for moving data collection and analysis in this direction. For example, these findings represent a broad sweep of outcomes for scientist participants at the Master's-level of training in a GK-12 Partnership Program. Combining these findings with those from other studies begins to define a parameter space of differential partnership outcomes that can guide the development of robust, cross-site and cross-programmatic instruments. Eventually, the development of a quantitative survey tool containing probes specific to all of the categories of benefits presented here and in other publications could allow *all* scientist participants to reflect on their learning experiences related to *all* of the emergent themes. Moreover, a quantitative survey could also be used with a comparison population of science graduate students not involved in formal pedagogy and partnership experiences to further examine the effect of integrating K-12 partnership and pedagogy experiences into the training of science graduate student scientists.

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