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Supporting the Development of Science Communication Skills in STEM University Students: Understanding their learning experiences as they work in middle and high school classrooms

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This paper examines the roles that 52 university Science, Technology, Engineering, and Mathematics (STEM) students play in an Interdisciplinary Science and Engineering Partnership that connects several middle schools, high schools, institutions of higher learning, businesses, and community institutions. It also examines the support these students feel are necessary to be successful in their roles, as well as what they feel the experience has taught them about science communication. Results from both qualitative and quantitative data, including surveys, interviews, observations, and artifact collection indicate that the most common experiences that the students had in the schools were assisting teachers in conducting labs, leading small group activities/discussions with students in class, demonstrating scientific content, procedures, tools, and techniques, and assisting teachers in teaching lessons. Most students felt these activities benefited their ability to work as a team, lead a team, facilitate group discussions, teach STEM concepts and methods, and generate others' interest in STEM research and activities. However, it was found that some tasks that the students were involved in provided more of a chance to practice their science communication skills than others. In order to be successful in these roles, nearly all of the students felt that support from the classroom teacher they were working with was necessary.

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In order to address the need for teacher professional development in interdisciplinary science inquiry, an Interdisciplinary Science and Engineering Partnership (ISEP) has been developed that connects several middle schools, high schools, institutions of higher learning, businesses, and community institutions in a northeastern region of the USA. The project focus is on teacher professional development with a spotlight on science inquiry content and pedagogical content knowledge through interdisciplinary science and engineering research experiences in science labs, development of science and technology classroom materials that are aligned with state learning standards, and inquiry-based curricula.

Specifically, the major activities that take place within this partnership include: (a) teacher professional development in which approximately 50 teachers partner with scientists from the university as well as community partners during the summer to conduct summer research; (b) the assignment of a full-time Science, Technology, Engineering, and Mathematics (STEM) PhD student and several part-time STEM undergraduate students to each school to support teacher implementation of interdisciplinary inquiry-based science instruction; (c) the creation of after-school science clubs and activities designed to expand student inquiry learning opportunities, to be staffed by STEM PhD students; (d) the creation of expanded Professional Learning Communities (PLCs) with mentoring relationships between middle and high school teachers and students, STEM college faculty, education faculty, STEM undergraduate and graduate students, volunteer STEM professionals, and parents; (e) extended learning opportunities and field trips to the science museum and the university; and (f) summer enrichment and university research internship programs for students.

The focus of this particular study is on the STEM graduate and undergraduate students involved in the partnership and their experiences in the schools. In addition to aiding the middle and high schools, one of the goals of the ISEP project is for STEM undergraduate and graduate students to develop better science communication skills that may help them in their future careers. Although the field of Science Communication is not new, the quotations below demonstrate that the importance of the field is becoming more well known recently:

> Science information is a social need that cannot be discarded in any full democracy. Society needs scientific information. (Greco, 2002, p. 2)

> Effective communication is an essential part of science for at least two reasons. First, if nobody hears about your work, you might as well have never done it. Second, if you do not communicate your work effectively, there are many people around who will communicate it for you, and when they do, it will probably be skewed in order to support whatever agenda they have. (Olson, 2009, p. 30)

> The fundamental goal of science is to develop a shared, public understanding of our observations. (Woelfel, 1992, p. 80)

> Check any online job-hunting website for science, technical, pharmaceutical, biotech, and medical jobs, and among the hundreds of listings, you'll find one common requirement: 'excellent communication skills'. (Barnard & St. James, 2012, preface)

Many of the books published on science communication are of the 'how-to' variety (American Association for the Advancement of Science, 2012; Barnard & St. James, 2012; Dean, 2009; Olson, 2009; Paradis & Zimmerman, 1997) which makes sense, as most research scientists have had little communications or public engagement training (The Royal Society, 2006; Thiry, Laursen, & Hunter, 2008). This is despite the fact that many PhD scientists and engineers cite teaching as their primary or secondary work activity (National Science Foundation [NSF], 2004) and science researchers take part in many science communication and public engagement activities (The Royal Society, 2006). A few theoretical frameworks for science communication have also been developed in recent years (Stocklmayer, 2001, 2013); they form the foundation of current science communication practices.

In looking at the history of science communication, the dominant mode of communicating science until the end of the twentieth century was the simple one-way transformation of information from an 'expert' to a 'receiver'. However, that ideal mode has shifted from a one-way transmission to some form of two-way, participatory practice (Stocklmayer, 2001, 2012). 'To be effective with any audience, communication must be an interactive process . . . Communication is essentially as much a matter of listening as it is of talking and, to be effective, each party must have some understanding of the other (Stocklmayer, 2001, p. 3). In order to engage the audience, science communicators must identify audience's preconceptions or alternative conceptions of science. Science communication is not just about knowledge and understanding; it depends as much on the interests and concerns of the audience as on those of the scientists or others in positions of social authority (Lewenstein, 1995). The Process of participation and engagement in science is a contextual one (Falk & Storksdieck, 2005). Falk and Storksdieck suggest three contexts to consider: Personal context, Sociocultural context and Physical context.

In the case of the ISEP program, the goal is to engage all of the participants in a PLC in which they all learn. Specifically, the aim for the college students is to learn effective science communication strategies by entering middle and high schools, interacting with students and teachers, and practicing the components of science communication in real-life contexts. These college students involved in ISEP are encouraged to collaborate with K-12 teachers in implementing interdisciplinary science inquiry by utilizing resources both inside and outside the classroom.

Literature Review

The idea for placing ISEP university students in the middle and high schools was modeled after the National Science Foundation (NSF) Graduate STEM Fellows in K-12 Education (GK-12) Program which pairs graduate STEM students with K-12 schools in order to improve their science communication and teaching skills while also elevating STEM content and instruction for the schools. The benefits of the GK-12 program have shown to be numerous for teachers, K-12 students, and university students.

Teachers

Teachers involved in the GK-12 program have reported increased STEM content knowledge (Gamse et al., 2010), a use of more effective pedagogical techniques (Gamse et al., 2010; Huziak-Clark, Van Hook, Nurnberger-Haag, & Ballone-Duran, 2007), greater access to STEM resources (Gamse et al., 2010; Moskal et al., 2007), greater confidence and preparedness to teach STEM concepts (Gamse et al., 2010; Stamp & O'Brien, 2005), increased technology instruction (Moskal et al., 2007), increased inquiry implementation (Gengarelly & Abrams, 2009; Huziak-Clark et al., 2007), and an increase in the number of real-world and interdisciplinary examples presented during classroom instruction (Moskal et al., 2007).

Students

In the studies that have been published, results conclude that the program has numerous benefits for the students. In their most recent evaluation of the GK-12 program (NSF, 2010), a majority of teachers indicated that the GK-12 program had positive effects on their K-12 students' STEM knowledge and skills. In her study of middle school students, Ferreira (2007) found that the students who participated in the program had access to scientists and mathematicians who shared with them how scientific knowledge is translated into real world applications. Students who were typically disengaged from the learning process showed increased interest in and positive attitudes toward science and mathematics. Laursen, Liston, Thiry, and Graf (2007) found that the K-12 students were engaged in authentic hands-on activities that generated interest in science and new views of science and scientists. Iskander and Kapila (2012) evaluated Project Revitalizing Achievement by Using Instrumentation in Science Education (RAISE), which was a partnership supported through a grant from the NSF GK-12 Fellows program. They compared RAISE high school classes to non-RAISE classes and found that: (a) a slightly larger percentage of RAISE project students took standardized exams; (b) a larger percentage of RAISE project students passed the exams; and (c) the average grade attained by RAISE project students was slightly higher.

STEM University Students

STEM students working in K-12 classrooms have reported gains as well. In their most recent evaluation of the GK-12 program (NSF, 2010), a majority of current and former graduate students indicated that their GK-12 experience benefitted their ability to conduct various activities requiring communication, teaching, and teamwork skills. A majority of their college faculty advisors also concurred that the GK-12 program helps their students develop skills in these areas.

Several other published studies have also reported on the positive effects of the GK-12 program on STEM students. In one study, (Thompson, Metzgar, Joeston, Shepherd, & Collins, 2002) the graduate students placed in secondary school science classrooms during the 2000–2001 academic year reported that they benefitted from enhanced understanding of science content, fuller understanding of the complexities of teaching science, and understanding of inquiry-based science teaching and its value. Researchers at Binghamton University, State University of New York (Stamp & O'Brien, 2005) reported that their graduate students improved their communication skills and understood the value of linear conceptual development in science curricula and their ability to facilitate that as teachers. Laursen et al. (2007) found gains of teaching, communication, and management skills; gains in understanding issues surrounding education and diversity; personal gains including growth in confidence and intrinsic or emotional rewards; as well as career gains such as resume enhancement and career path clarification. Year-end interviews with college advisors as well as pre- and post-questionnaires completed by students at Cornell University's GK-12 program indicated beneficial impacts on some of the graduate students' research and scientific knowledge, accompanied by increases in their teaching, communication, and time management skills and by the ability to effectively incorporate outreach into their future careers as professional scientists (Trautmann & Krasny, 2006). In a study conducted by Page, Regens, and Wilhelm (2011), graduate students reported improvements in confidence and ease of speaking while teaching audiences of all ages. GK-12 students involved in a partnership between Polytechnic Institute of New York University and several New York City high schools reported that the experience helped them in developing their own science skills (Iskander & Kapila, 2012).

While the benefits of college students working in K-12 schools have been documented, little has been reported on exactly what types of support are necessary in order for them to have a good experience, and which aspects of science communication they are practicing while working in the schools, which is the purpose of the present study. Specifically, the following questions guided the research:

(1) What activities are these STEM students engaged in?
(2) What types of support do these students feel are necessary for them to successfully work with adolescents in science?
(3) What do these students feel their experiences in K-12 schools have taught them about communicating science to students?

Description of the ISEP program

The ISEP program targets middle and high school science and technology learning and is located in the northeastern region of the USA. The collaboration is a rather large one; its core partners include two institutions of higher education and 12 schools, all located within one urban public school district. The 12 schools have been identified as high-needs schools and include five elementary/middle schools, and seven high schools. Supporting partners also include a science museum, a global Fortune 300 engineering company, a cancer research center, a private medical research organization, a service-learning coalition that includes 10 colleges and universities (including the core partners) along with over 70 service agencies, and a district parent coordinating committee. At the time of this writing, the partnership is in the second year of the operational phase.

The partnership is funded by the NSF as part of its Math Science Partnership program. The partnership was designed to target the middle school experiences of students in science and engineering as they transition to high school. The project focus is on teacher professional development with an emphasis on science inquiry content and pedagogical content knowledge through interdisciplinary science and engineering research experiences in science labs, development of science and technology classroom materials that are aligned with state science learning standards, and inquiry-based curricula. The partnership was designed to take a mentoring approach to teacher professional development by creating PLCs or collaborative working groups, that are geared toward cultivating mentoring relationships with middle and high school teachers and students, STEM college faculty, education faculty, STEM undergraduate and graduate students, volunteer STEM professionals, and parents.

A key component of the program is to integrate the latest interdisciplinary scientific and engineering research approaches into the experience base of middle and high school teachers. The intent is for teachers to develop interdisciplinary science inquiry knowledge while being supported by PLCs. The goal is for that knowledge to be translated into pedagogical content knowledge that will ultimately improve the science learning of students. Approximately 50 science teachers per year will have the opportunity to access research through multiple science and engineering experiences and to develop classroom materials that are aligned with state learning standards and draw from multidisciplinary approaches. The research experiences will be linked to intensive leadership development training, in which teachers will develop challenging science courses and curriculum materials, aligned directly with national and state learning standards. The aim is that teachers will enhance their mentoring skills and learn to form expanded PLC teams of science educators within their schools. As a result, the partnership anticipates that approximately 3,000 students from grades 6–12 will benefit from the classroom materials and related activities that are generated annually.

Mentoring is another large component of the partnership. Besides master teachers mentoring other teachers in their buildings, graduate and undergraduate students will be mentoring middle and high school students, teachers will mentor graduate students in pedagogical methods, graduate students will mentor teachers in science content, and university faculty and volunteer STEM professionals will mentor middle and high school teachers and students. There is also a concerted effort to increase parent participation in the direction of the program, and to foster an understanding and interest in children's science education. The targeted schools enroll a majority of minority and low-income students, providing a means to broaden the participation of under-represented students in STEM fields. The overall conceptual framework for the partnership that was submitted to NSF is shown in Figure 1. The specific activities that will take place throughout the partnership can be found in Figure 2.

Method

This research takes a mixed-methods approach and included various methods of data collection and analysis. The data collected were extensive and drew upon multiple sources of information and settings. They were all collected during the 2011–2012 and 2012–2013 school years. During this time, 70 college students participated in the program including 18 non-STEM students and 52 STEM students. The present study focused on STEM students. We wanted to triangulate the data collected from all of these students, therefore all of them were contacted to be observed, participate in taking a survey, and to be interviewed. The data below were compiled from students that agreed to participate. The university's Institutional Review Board reviewed the data collection procedures and instruments to ensure that they met research ethical standards.

Observations

These data included a total of 43 observations. Eleven observations were conducted in school classrooms where college students were working with middle and high school students. Twenty-one observations were conducted in a college classroom where

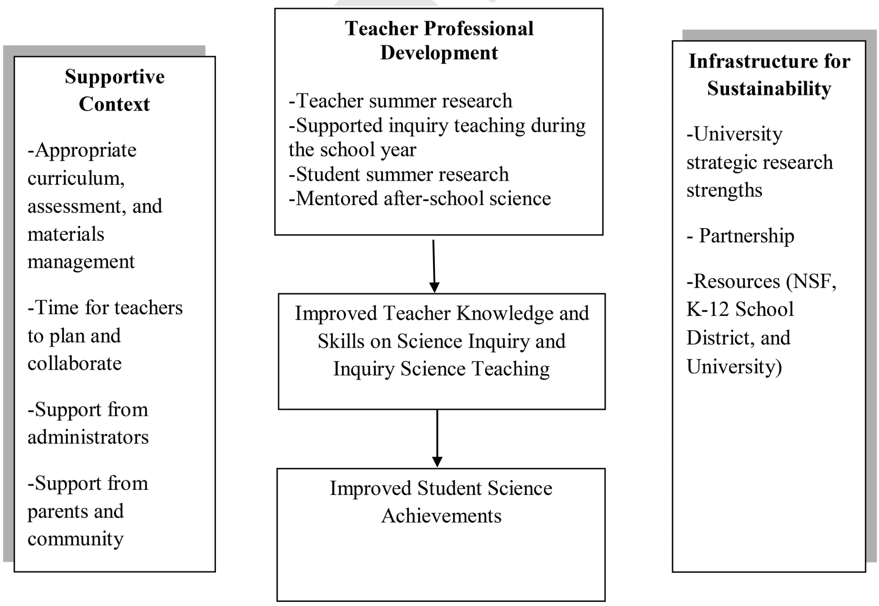

Figure 1. Conceptual framework for the partnership.
Source: Project description submitted to the NSF

Figure 2. Major activities to take place within the partnership.
Source: Project description submitted to the NSF

graduate and undergraduate students were preparing to work in middle and high schools. This was a seminar course that met once per week for the undergraduate students and on an 'as-needed' basis for the graduate students. Four observations were conducted at after-school activities: an academic fun night where students and their families participated in activities related to STEM careers and professions at an elementary/middle school, two science nights at elementary/middle schools where students and their parents participated in hands-on science activities, and an after-school enrichment science program for middle school students. Three observations were of PLC meetings where teachers worked in collaborative groups, and four observations included miscellaneous partnership meetings with coordinating principals, teachers, STEM students, the principal investigator and program administrators. Descriptive field notes were taken at all of these observations and helped to give a context to the other data that were collected.

Physical Artifacts

Physical artifacts were collected at all of the observations. These included meeting agendas and handouts, lesson handouts and materials, and anything given away at after-school activities.

Interviews

Semi-structured, face-to-face interviews were conducted with 13 undergraduate STEM students, and 14 graduate STEM students. These interviews included six students who continued in the program for over a year, and agreed to be interviewed again during year two. With the interviewees' permission, interviews were audio-recorded and transcribed verbatim by the researcher to ensure that the perspectives of the college students informed the research. The interviews typically lasted around 45 minutes. However, the shortest interview was just over 15 minutes and the longest interview lasted approximately 90 minutes. Participants were asked a variety of questions regarding their partnership experience, however the questions that guided this research were: (a) What kinds of support do you think are necessary for you to successfully work with adolescents in science? (b) What have you been doing in the schools? (c) Can you name something that you think has gone well? (d) Can you name something that you think has gone poorly? (e) Is there anything that you think can be done to improve the program? and (f) What has this experience taught you about communicating science to students?

Relevant Documents

Relevant documents were collected during the 2011–2012 and 2012–2013 school years pertaining to the partnership. All undergraduate students involved in the partnership submitted at least 10 journal reflections describing their experiences in the partnership. Archival records were collected, including the partnership proposal for funding from NSF as well as project summaries and reports.

Surveys

Surveys were given to all of the university students involved in the partnership, both graduate and undergraduate. It included questions about their preparation prior to going into the schools, experiences in the schools, perceived values of the partnership, and their background.

Data Analysis

Data analysis activities began simultaneously with the data collection, as patterns were followed and meaning was made of the data during the data collection process. The interviews were audio-recorded and transcribed verbatim. This interview data, along with the other qualitative data, were analyzed for codes and themes with respect to answering the research questions. To supplement the qualitative data, descriptive statistics were calculated on the surveys. Then, multiple forms of evidence were found to support each category or code and larger themes emerged from the data. For the purpose of confidentiality, pseudonyms were used for all school, person, and place names.

Findings

The Roles of Students in the Schools

The ISEP partnership was a rather large one, involving 12 high-needs elementary/middle and high schools in an urban school district located in the northeastern region of the USA. The college students worked with middle and high school students and teachers at these schools. Because the needs of the students and teachers at each school varied, the STEM students did not receive instruction as to what exactly they would be doing in the schools. Rather, that was left for them to navigate with the teachers once they arrived. Therefore, the first research question set out to find what roles these students were fulfilling in the schools. Of the 52 STEM students involved in the program, 33 were STEM undergraduate students and 19 were STEM graduate students. Table 1 presents the descriptive statistics of activities engaged by those students.

From Table 1, we can see that the most common experiences that both the undergraduate and graduate students had in the schools was assisting teachers in conducting labs, leading small group activities/discussions with students in class, demonstrating scientific content, procedures, tools, and techniques, and assisting teachers in teaching lessons. In visiting both the middle and high schools, we observed that they were not conducting these activities in front of the whole class. Rather, we observed that the most common activity that the university students, both graduate and undergraduates, were doing was working with students one-on-one. This included walking around and aiding students with their assignments, labs, and projects, as well as tutoring one-on-one. University students also tutored and aided students working in small groups.

Table 1. Descriptive statistics of student experiences in schools ($n = 52$)

Activity	Undergraduate frequency (%) ($n = 33$)	Graduate frequency (%) ($n = 19$)
Assisted teachers in teaching lessons	24 (72.7%)	12 (63.2%)
Assisted teachers in conducting labs	26 (78.8%)	14 (73.7%)
Developed science labs for class use	9 (27.3%)	12 (63.2%)
Developed out-of-school science learning activities	3 (9.1%)	7 (36.8%)
Led small group activities/discussions with students in class	27 (81.8%)	13 (68.4%)
Led small group activities/discussions with students after school or during weekend	4 (12.1%)	6 (31.6%)
Demonstrated scientific content, procedures, tools, or techniques to students	25 (75.8%)	14 (73.7%)
Helped teachers find relevant resources (e.g. science activities)	8 (24.2%)	14 (73.7%)
Presented lessons/lectures to students in class	10 (30.3%)	8 (42.1%)
Tutored students after school or during weekends	1 (3%)	1 (5.3%)
Other	1 (3%)	1 (5.3%)

While aiding students one-on-one or in small groups was the primary activity observed by both the graduate and undergraduate students in the schools, after that, the difference between the graduate and undergraduate roles in the schools became more distinct. The undergraduates helped more with classroom management primarily by trying to keep kids on task, answering questions, and passing out materials. The following is a comment from an undergraduate student who worked in a high school setting:

> That's ultimately what probably like sixty percent of what I do is just keeping kids like, 'Remember, we are supposed to be reading right now and not talking about, I don't know, Jersey Shore or something.' And that really helps, keeping kids on task and making sure they're interested, and having fun with them. (Paul, undergraduate student)

While working in small groups and aiding in classroom management were the primary roles of the undergraduate students, there were some who participated in other tasks at the schools. Some described giving input into lectures, by either commenting on what the teacher was talking about, creating their own mini-lectures, or finding videos that reinforce concepts that the teacher is discussing. One group of students, who worked in a middle school, described creating a science exploration lab at their school, where teachers could bring their students to complete in lab activities. These students decorated the classroom, then created and implemented various lab activities. Some students also helped with after-school science activities where they primarily worked with students in small groups, or did demonstrations in an after-school science night for students and parents. Some students helped to chaperone field trips or school activities, and some students helped the teacher to find resources such as science articles or websites.

Like the undergraduate students, the graduate students primarily worked with students one-on-one or in small groups, assisting in labs and lessons, and in demonstrating scientific content. However unlike the undergraduate students, they were very involved in helping the teachers to locate resources and in developing labs for class use. In their interviews, they also describe being more involved with administrative-type tasks. The graduate students in the schools served as the liaison between the school and the university. For example, if the schools wanted to order supplies or plan field trips through the partnership, these requests went through the graduate students. Also, the graduate students often managed the undergraduate students and coordinated which classrooms the undergraduate students went into.

Besides aiding small groups of students and assisting teachers in locating resources and developing labs, the roles of the graduate students varied in the schools. One graduate student helped with developing a curriculum, as that was one of the main goals of the school. Several graduate students were also found participating in after-school science clubs and activities, where they worked with students in small groups or did science demonstrations for students and parents. The graduate students also coordinated field trips to the university science laboratories.

When asked about what went well during their time at the school, the most common answer of both the graduate and undergraduate students was their interactions with the students, either when they helped them with their schoolwork or when they got to know them on a personal level. For example, the following is an excerpt from the journal of an undergraduate student that worked in a high school setting,

> One boy was telling me how he was a (third year high school student) and he was a very good football player. He expressed his interest in (name of university). I got super excited and I finally got to give some advice to a student! Prior to this I was mostly only interacting with (first and second year students) so I wasn't able to really talk much about college plans etc. I told the boy how important it was to stay focused and stay motivated on his goals. He said he was willing to do anything to make a difference in his own life. I found this to be one of the best moments in my mentoring experience because I was able to give him a personal story and give him my own thoughts. (Dee, undergraduate student)

The following is from an interview with an undergraduate student that worked in a high school setting:

> Actually, the teacher showed me something, the lab that we did on variation. There were two questions on the test that he gave them on variation. He took the 8 kids that I worked on the lab with. And every single one of them got at least one of the questions right. And there were a couple that got both of them right. And I mean, from my school that might not have been great but from this school it was fantastic 'cause most of the time the kids are missing the question. If you look at a question more than 50% of the kids are gonna miss it. So, uh, the teacher's like, 'That's just a perfect example that this works. It actually helped the students.' I was really happy about that. (Jason, undergraduate student)

It became clear from the interviews and journals that the students felt most fulfilled when they believed that they had actually made a difference and related to the students on a personal level. Almost all of the schools involved in ISEP are high-needs schools. To Jason, who did not come from a high-needs school district, it was fantastic that the students he was working with got at least one of the questions right on the topic. While most undergraduate and graduate students felt that their interactions with the students are what went well, after that, their responses were quite diverse. One undergraduate student mentioned that what he thought went well was that he gained skills for working with children. A graduate student mentioned that a lab she created went well. An undergraduate student mentioned that he was utilized well in the classrooms that he was in. An undergraduate student reflected fondly on a time that he took over the class because there was a substitute teacher that did not know what the students were supposed to be doing. Another undergraduate student mentioned the fact that the partnership had expanded to include more schools went well, and a graduate student mentioned the fact that teachers are starting to embrace a particular science curriculum is something that went well.

At one particular middle school, both the graduate student assigned to the school as well as the undergraduate students assigned to the school spoke highly of a science exploration lab that they all created and helped to implement. It involved a number of small laboratory activities set up in one room that the undergraduate students helped to decorate. Each undergraduate student created and was in charge of one of the different stations. The classroom teacher and the graduate student helped students to circulate among the different stations. The undergraduate students created a chart with the middle school students' names and list of skills, so that they could keep track of students that mastered a particular skill.

Necessary Support

When asked about the support necessary for them to work with adolescents in science, the overwhelmingly most common answer given by both the graduate and undergraduate students was support from the classroom teacher. This finding is also in line with the Laursen et al. (2007) study which found that emotional costs were incurred by the university students when teachers did not support them. The following is an excerpt from Mary, a graduate student working in a high school,

> . . . having a teacher there who's used to teaching classes and used to teaching at that level because like the one lab that I designed, I wrote it all out and the teacher's looking at it and she's like, 'We're gonna need to water this down a little bit.' So knowing what, that's one big support I guess, knowing what level you should be teaching at so you're not going way over but then also at the same time so that you're not going way under then boring them. You need to find that medium of where the students are at. Having those teachers is very helpful for that.

As for the undergraduate students, the second most cited answer was guidance from the university seminar course that they were taking was necessary. The following is from an interview with Erica, an undergraduate student working in a middle school:

> Well, I definitely think the (name of school district) teachers are like a good support. I think that they should kind of teach us about how their classroom is run and what they expect from us and, um the kids' different needs, and how to address them, and I think that's really, really important. From (name of university), I think that we had a really good support system in the classroom with (name of instructors). I think that it was nice to come back into their classroom and talk about the issues and knowing that what we said wasn't going to go directly back to the teachers or to the school. So I think that was a really good strong support system. That was really nice.

One of the undergraduate students also mentioned that materials were important and that you also needed support of the administration.

While teacher support was the most cited answer, the graduate students also mentioned that you need good communication lines, support from your peers or other graduate students involved in the project, funding, and space.

When asked about what could be improved in the program, all of the undergraduate students interviewed mentioned either having more contact in the schools or teachers who better understood the program. The following is an excerpt from an interview with Paul, an undergraduate student working in a high school:

> I kinda wish you could just go more often. It's kind of annoying being like still a student and going to the place. Um, other ways which could be improved? Like, the teachers still, I don't know if it's because, like I said, maybe it will change as time goes on if we do this more. But the teachers still don't seem to really understand, like they understand a little

> more, but they don't seem to do as much, be prepared as much for us, which I think I heard a lot of the kids say. They feel like the teachers aren't completely prepared for them.

These things were not cited by the graduate students however. The graduate student answers varied greatly. Their responses were that the expectations of them should be spelled out more prior to the beginning, teachers who are more open-minded, more consistency in undergraduate students coming into the schools, and better coordination of scheduling.

When asked if there was anything that went poorly, the most common answers cited were centered upon the fact that not all teachers used the university students in their rooms to their fullest potential. They described sitting in the back of the room during lectures and watching films. For example, the following is from the journal of an undergraduate student that worked in a middle school:

> It seemed to me that they didn't have a well-thought out plan in place for how to utilize us and let us interact with the students. As the weeks went on, I began to feel more and more like an extra set of hands instead of a useful mentor. (Michael, undergraduate student)

This issue seemed to improve somewhat in year two however, as many of the teachers who did not make the most of students during the first year, did not get assigned students the second year. The other most common answer had to do with time, which was an issue also addressed in the studies by Thompson et al. (2002) and Laursen et al. (2007). Some students mentioned their time commitment to the schools interfering with their studies. Graduate students mentioned difficulties in managing the undergraduates who were assigned to be there a couple of times a week, and navigating the middle and high school schedules which often diverged from the college schedules. The following is an excerpt from an interview with Bill, a graduate student who worked with middle school students:

> . . . there's an issue with the gap between the high school/middle school calendar and the college calendar. For me like I said, it doesn't make a difference. I'm there year 'round. But for I think what could definitely be improved upon because it has not gone well is the undergrads and the class schedule; working that out. We do have a part-time student at our school. An undergrad that gets paid. So she is um, there for 6 hours a week or whatever her time is, but during breaks and stuff you know, they're off and they're gone. So I think we could definitely improve on that because like I said for two months there we had to shut things down. And, that kinda sucks because things were kind of rolling right along and then we really, you know ended up hitting a wall and having to start over again when you take a break like that. (Bill, PhD student)

In regard to time, the undergraduate students mentioned scheduling, but mostly the short amount of time that they were in the classrooms. Due to the fact that they were taking other classes during the day, they typically went into the schools once or twice per week. Sometimes the undergraduate students were even assigned to two schools, so they were only in each school once per week. Moreover, since they were taking this as a semester class, they only went into the schools for one semester, although some continued in the program. When factoring in university breaks, school days off, and time at the beginning of the semester to get schedules together, most undergraduate students went into the schools about 10 times. Many cited that the shortage of time did not allow them to make as many personal connections with the students as they would have liked. This is also in line with the Laursen et al. (2007) study in which the university students expressed frustration at seeing new groups of students each day, without a chance to build relationships with students or see their progress. The following is a journal excerpt from Brenna, an undergraduate student who worked with high school students,

> The way my schedule came out didn't coincide well with the rotations of classes at (School A), my first school, which led to inconsistency in my times seeing the kids, which meant I couldn't form consistent bonds with any of the students. Though I could help by clearing misconceptions and helping out that day, I believe I was seen as little more than a transient aide. I was only at my second school (School B), for one day then we were told we weren't needed anymore which was a bummer for me. Soon after, (School A) was just doing state testing, so I was reassigned to (School C) and (School D) which is six minutes from my house. These schools would have had things for me to do, but since I was only to be there for two weeks, I could not interact with the students to the level which I had hoped for and anticipated. (Brenna, undergraduate student)

Along those same lines, one undergraduate student mentioned that something that went poorly is that there was a lack of communication and that the program was a low priority in the school.

While the lack of time and lack of being utilized properly were the primary things that the undergraduate students felt went poorly, these students also cited a variety of other things that they think went poorly. For example, one student mentioned that when he was not familiar with the material that was being taught he thought it went poorly. Another mentioned that it was just a difficult setting in general and another said it was difficult to get the students interested in the material. Besides scheduling and time, four of the graduate students did not have a comment as to what they think went poorly and one mentioned student attendance in the schools as being low.

When teachers were asked about the contribution of the STEM students in their classrooms, none of the teachers expressed that they were 'no help' or a 'hindrance'. Most of the teachers felt that they did help in some way, at least by helping to keep students on task. However, several teachers felt that the students that were assigned to them were an 'off pairing' if the students' area of study did not match up with the subject being taught in class.

Science Communication

Science communication involved in this present study referred to university STEM students engaged with K-12 students and teachers as they were implementing interdisciplinary science inquiry. The purpose was to improve K-12 students' science learning experiences as well as the science communication skills of university students both inside and outside their classrooms. We summarized STEM students' science communication experiences in three aspects: define your audience, develop your message, and explain science. When asked about what this experience taught them about communicating science to students, the participants explained a wide variety of things that they learned, of which we are going to discuss in the context of these three principles.

Define your audience. An important part of science communication is defining your audience. One must take into account the interest, background knowledge and attention span in order to have participatory interaction. In a study by Hsu and Roth (2010), when members of the scientific community who were working with high school interns were asked for suggestions to better facilitate communication for future internships, they emphasized the need for considering high school students' background and prior knowledge before developing a plan and even suggested having the scientists actually go into high school classrooms and interact with high school students prior to working with them on an internship.

Of all three principles, most of the STEM student responses expressed that they realized that you have to know your audience, with the most common answer being that you have to communicate at their level. The following is an excerpt from an interview with George, an undergraduate student who worked in a high school setting:

> I definitely learned a lot about how to gage the levels of the same subject 'cause teaching chemistry for (a first-year high school student) and chemistry for (a fourth-year high school student) is a very different chemistry. Same with biology. Everything becomes very different. How you explain things has to be very different. You can't, I mean you're always tempted to explain a chemical subject with a more intense chemical subject because you took a class on the explanation for that already. But you have to turn around and be like, 'Well, water likes water and they mix nice. Like dissolves like.' That makes sense to a younger student whereas you can step in and say, 'Polar attractions and this and that' with a senior level student and for college-level students it's a whole new ball game.

Besides educational level, students also mentioned that you have to take their backgrounds into account, that you must connect with the students, and that you must focus on their questions, inquiries, and interest.

Develop your message. In Science Communication, scientists must identify their key ideas and/or messages. After identifying the key message(s), the scientist must make many decisions: how much information to share about each of the ideas; how he/she is going to convey the message, and how much time to spend on each of the ideas or messages. In regard to developing a message, few students discussed learning anything in this regard, which makes sense, as when examining what they were doing in the schools, only a minority of the students actually made decisions about curriculum or lesson planning. However, when answering questions, these students still have to develop an answer. For example, in an undergraduate student journal, Sadie explains that a student asked her, 'What is Chemistry?' According to her journal, this is how she responded to a middle school student,

> Thinking of how to describe it in a simple way that I knew he would be able to understand I related it to biology, something he had already taken and passed. 'You know how in

> Biology you learned about how cells are the building blocks of life and make up all living things? Well in chemistry you learn about the ‘cells’ of non-living things. They’re called atoms. You see that desk and that cardboard box? They could be made up of exactly the same atoms but in a different structure.

Explain science. In explaining science, there are many things to consider: the interaction with the audience, presentation modes to use, pause time and time for reflection with the audience, and ways for collecting feedback. In this regard, students mentioned learning that you have to relate the material to something that they know already, you have to vary your instruction, and that one must hone into the questions, inquiries, and interest of the students. The following is an excerpt from an interview with James, a graduate student who worked with high school students:

> It taught me a lot. Number one it taught me that students, although they may not think they’re interested in science, they have a lot of questions about it. So if we can kinda just hone in on their questions about it and then grab their interest or attention based on their questions and redirect them to science, I think that’s the key. Um, everybody has questions about something like uh, and they may not know that it’s in relation to that field but . . . for example, someone may say, ‘Why doesn’t space have light?’ Well, that’s a good starting point to explore. Yes, that’s related to science. Let’s explore that. So if we can kind of capture their interest a little bit and kinda explore their interest through science I think that goes a long way.

Some students, when asked what they learned about science communication, also spoke in general terms, for example, ‘it’s difficult’, ‘it’s important’ or ‘it takes a lot of effort.’

Benefits to Science Communication

Table 2 presents descriptive statistics of student perceived benefits from their experiences in K-12 schools.

From Table 2, we see that most of the students felt that their experiences within this partnership benefited their ability to do a number of things. These include work as a team, lead a team, facilitate group discussions, teach STEM concepts and methods, and generate others’ interest in STEM research and activities. The graduate students felt more strongly that the partnership benefitted their ability to develop instructional materials about STEM concepts and methods and their ability to explain STEM research and concepts to a public audience. Whereas the undergraduate students felt more strongly that the partnership benefitted their ability to understand science concepts better. This variation makes sense as the graduate students were more commonly found actually creating instructional materials for the teachers to use.

Benefits of K-12 experiences on science communication are also demonstrated on their responses to the survey questions on their future careers. Table 3 presents the descriptive statistics of student perceived benefits on their career choices.

Table 2. Descriptive statistics of student perceived benefits from their experiences in schools ($n = 52$)

Statement	Strongly disagree	Disagree	Agree	Strongly agree
Work on a team				
Graduate ($n = 19$)	0 (0%)	1 (5.9%)	14 (82.4%)	2 (11.8%)
Undergraduate ($n = 33$)	1 (3%)	5 (15.2%)	20 (60.6%)	7 (21.2%)
Lead a team				
Graduate	0 (0%)	3 (17.6%)	9 (52.9%)	5 (29.4%)
Undergraduate	1 (3%)	6 (18.2%)	20 (60.6%)	5 (15.2%)
Facilitate group discussions				
Graduate	0 (0%)	1 (5.9%)	13 (76.5%)	3 (17.6%)
Undergraduate	0 (0%)	0 (0%)	21 (63.6%)	12 (36.4%)
Teach STEM concepts and methods				
Graduate	0 (0%)	0 (0%)	10 (62.5%)	6 (37.5%)
Undergraduate	0 (0%)	3 (9.1%)	20 (60.6%)	10 (30.3%)
Develop instructional materials about STEM concepts and methods				
Graduate	0 (0%)	1 (5.9%)	14 (82.4%)	2 (11.8%)
Undergraduate	1 (3.1%)	14 (43.8%)	14 (43.8%)	3 (9.4%)
Generate others' interest in STEM research and activities				
Graduate	0 (0%)	0 (0%)	10 (58.8%)	7 (41.2%)
Undergraduate	0 (0%)	4 (12.5%)	21 (65.6%)	7 (21.9%)
Conduct research as part of a collaborative team				
Graduate	1 (6.3%)	6 (37.5%)	8 (50.0%)	1 (6.3%)
Undergraduate	3 (9.1%)	14 (42.4%)	14 (42.4%)	2 (6.1%)
Conduct independent research				
Graduate	1 (6.3%)	7 (43.8%)	8 (50.0%)	0 (0%)
Undergraduate	2 (6.1%)	16 (48.5%)	13 (39.4%)	2 (6.1%)
Develop a research and/or technology agenda				
Graduate	0 (0%)	5 (29.4%)	12 (70.6%)	0 (0%)
Undergraduate	2 (6.1%)	20 (60.6%)	11 (33.3%)	0 (0%)
Write papers and reports about my work				
Graduate	2 (11.8%)	11 (64.7%)	3 (17.6%)	1 (5.9%)
Undergraduate	2 (6.1%)	8 (24.2%)	18 (54.5%)	5 (15.2%)
Present my work at a professional conference				
Graduate	2 (12.5%)	10 (62.5%)	4 (25.0%)	0 (0%)
Undergraduate	2 (6.1%)	24 (72.7%)	7 (21.2%)	0 (0%)
Explain STEM research and concepts to public (non-technical) audience				
Graduate	0 (0%)	0 (0%)	12 (70.6%)	5 (29.4%)
Undergraduate	1 (3.1%)	13 (40.6%)	16 (50.0%)	2 (6.3%)
Decide a career in education				
Graduate	2 (11.8%)	5 (29.4%)	8 (47.1%)	2 (11.8%)
Undergraduate	0 (0%)	15 (45.5%)	13 (39.4%)	5 (15.2%)
Understand science concepts better				
Graduate	0 (0%)	6 (35.3%)	7 (41.2%)	4 (23.5%)
Undergraduate	3 (9.1%)	5 (15.2%)	18 (54.5%)	7 (21.2%)

From Table 3, we see that for most students, their experiences in the partnership did not increase their interest in conducting research, but it did increase their interest in influencing public policy related to STEM education. As for the graduate students, their interest in teaching at the college/university level increased, while the undergraduate students' interest in teaching at the K-12 level increased.

Discussion

The ISEP program is a five-year grant that has just completed year two. There are many things that the program can do to improve for future years. Others contemplating similar projects may find these findings helpful as well. One major component of the ISEP partnership is college graduate and undergraduate students going into 12 different middle and high schools to aid the teachers with interdisciplinary science inquiry and to improve science communication skills for themselves. Previous research has shown that STEM students working in K-12 classrooms report improvements in communication skills (Laursen et al., 2007; NSF, 2010; Page et al., 2011; Stamp & O'Brien, 2005; Trautmann & Krasny, 2006). In the current research, students reported that the particular aspect of science communication that they learned was the importance of defining your audience. Most of the students interviewed expressed that you have to know your audience and be able to communicate at their level.

Because there are so many different schools and teachers involved in this partnership, the college students going into the schools have a variety of different experiences. Some of these activities give the students more opportunities to practice science communication, while some activities offer less. The activity that undergraduate and graduate students are doing often in the schools is working with students one-on-one or in small groups. In doing this, college students have the opportunity to practice the three main components of science communication: know your audience, create your message, and explain science. Many students in this study have learned that

Table 3. Descriptive statistics of student perceived impact on their future careers (n = 52)

Statement	Strongly decreased	Decreased	Was unchanged	Increased	Strongly increased
My interest in conducting research					
Graduate (n = 19)	0 (0%)	1 (5.9%)	10 (58.8%)	5 (29.4%)	1 (5.9%)
Undergraduate (n = 33)	0 (0%)	1 (3%)	19 (57.6%)	9 (27.3%)	4 (12.1%)
My interest in teaching at the college/university level					
Graduate	0 (0%)	0 (0%)	4 (23.5%)	9 (52.9%)	4 (23.5)
Undergraduate	0 (0%)	0 (0%)	21 (63.6%)	6 (18.2%)	6 (18.2%)
My interest in teaching at the K-12 level					
Graduate	1 (5.9%)	3 (17.6%)	6 (35.3%)	6 (35.3%)	1 (5.9%)
Undergraduate	2 (6.1%)	3 (9.1%)	9 (27.3%)	13 (39.4%)	6 (18.2%)
My interest in influencing public policy related to STEM education					
Graduate	0 (0%)	0 (0%)	1 (5.9%)	8 (47.1%)	8 (47.1%)
Undergraduate	0 (0%)	0 (0%)	12 (36.4%)	13 (39.4%)	8 (24.2%)

you must take student background, abilities, and prior knowledge into account when explaining science concepts to them. Because many of the college students in the study have stated that their main goal for the program is to form personal relationships with students and help them with their studies, working with students one-on-one or in small groups is a formidable way for them to form these bonds as well as develop their science communication skills. In working with smaller groups of students, there is more opportunity for the two-way, participatory interaction that is so essential to science communication. When asked about what went well in the schools, it is often these personal interactions that the college students favor.

Many of the undergraduate students in the study mentioned walking around the classroom, keeping students on task while the teacher is trying to lecture. While this may be of great help to the teacher, this may not be the best way for these college students to develop their science communication skills. In regard to classroom management, many of these students are unsure of the role they play in the classroom, and while they do want these middle and high school students to realize that you have to pay attention to be successful, they do not want to be a disciplinarian to the students.

One experience that was spoken highly of by the undergraduate and graduate students, as well as the head of the science department at the school, was the creation of a science exploration lab. The head of the science department set aside a room in the school to create a science exploration lab that other science teachers could bring their students to. The undergraduate students were to each design a small lab activity, and the students were to circulate through all of these labs, with the help of the undergraduate and graduate students. The undergraduate students also were assigned the task of decorating the classroom. They created a 'tree of knowledge' where on the leaves, the middle school students wrote down things they learned by doing the labs. They also created charts to keep track of which students mastered certain skills in the lab. The head of the science department and the graduate student spoke highly of this activity because the middle school students had the opportunity to practice skills and use vocabulary that may appear on the upcoming state assessments. The undergraduate students spoke highly of being able to create different labs, decorating the classroom and then actually implementing the labs that they created. The downside to this activity was when the college semester ended, the undergraduate students were not available to run all of the different labs, so the activity came to a halt until a new semester started and a new group of undergraduate students entered the school. This conflict of schedules and shortage of time was a theme that ran through most of the interviews and student journals. Time was also a negative outcome reported in previous studies by Laursen et al. (2007) and Thompson et al. (2002).

Unfortunately, not all of the activities that the college students were involved in were as positive as the experience in the science exploration lab. Many students described not being used to their fullest potential, and having their time wasted by sitting in the back of a classroom listening to a lecture, watching a film, or not knowing what to do if there is a substitute teacher because the assigned teacher was absent. In contrast to the experience in the science exploration lab, these students felt like they did not have a purpose in the classroom. This finding is in line with the Laursen et al. (2007) study which found that emotional costs were incurred by the university students when teachers did not support them. Perhaps if these teachers gave these college students a purpose, they would have had a more positive experience, particularly because both the graduate and undergraduate students overwhelmingly responded that the support they needed to work with adolescents in science was support from the classroom teacher. Those students who actually felt as if they contributed to the lesson, even if it was just a short video clip they found to add to a lecture, viewed their experience in a more positive way and actually had an opportunity to practice their science communication skills.

In order for STEM students to fully benefit from working with K-12 students in terms of developing their science communication skills, findings reported above suggest that they need support from the classroom teacher, and they need to feel that they have a purpose in the classroom. The main goals of most of these STEM students were to form personal relationships with students and to help them with their studies. Working with students one on one or in small groups provided a way for students to form bonds with students as well as to develop their science communication skills. In particular, these students learned the importance of defining their audience and communicating at their level by taking into account their background, abilities, and prior knowledge.

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