STEM Students as Facilitators of Interdisciplinary Science Inquiry Teaching and Learning

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Abstract

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 many middle schools, high schools, institutions of higher learning, businesses, and community institutions in a northeastern region of the United States. The partnership was designed to include university STEM students, both graduate and undergraduate, who play a role by working in the schools, working with teachers during their summer research, and by participating in Professional Learning Communities (PLCs), all of which are intended to facilitate interdisciplinary science inquiry (ISI) teaching and learning in the schools. The focus of this study is to examine the interactions between the university STEM students assigned to the schools and the teachers involved in the ISEP project to learn how STEM students may play a role in building the ISI knowledge of K-12 teachers and in changing their teaching practices.

Introduction

The National Research Council of the National Academy of Sciences (2012) has released a framework for the next generation of science standards to improve all students' understanding of science. This framework consists of three main dimensions that are to be integrated into standards, curricula, instruction, and assessment: (a) scientific and engineering practices; (b) crosscutting concepts that have common applications across fields; (c) core ideas in four disciplinary areas: physical sciences, life sciences, earth and space sciences, and engineering, technology, and the applications of science. This new reform document represents a new vision for science teaching and learning to move from science inquiry to interdisciplinary science inquiry. While it is suggested that students will make the greatest strides when all components of the system, including professional development for teachers, are aligned with the vision of the framework, the creators of this framework recognize the challenge this presents in relation to teachers' familiarity with these new instructional practices.

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 many middle schools, high schools, institutions of higher learning, businesses, and community institutions in a northeastern region of the United States. 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 science learning standards, and inquiry-based curricula.

Specifically, the major activities that take place within the partnership include: 1.) teacher professional development in which approximately fifty teachers partner with scientists from the university as well as community partners during the summer to conduct summer research; 2.) the assignment of a full-time STEM PhD student and several part-time STEM undergraduate students to each school to support teacher implementation of interdisciplinary inquiry-based science instruction; 3.) the creation of after-school science clubs and science nights designed to expand student inquiry learning opportunities, to be staffed in part by STEM PhD students; 4.) the creation of expanded Professional Learning Communities 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; 5.) extended learning opportunities and field trips to the science museum and the university; 6.) summer enrichment and university research internship programs for students.

The focus of this study is to examine the interactions between the university STEM students assigned to the schools and the teachers involved in the ISEP project to learn how STEM students may play a role in building the interdisciplinary science inquiry (ISI) knowledge of K-12 teachers and in changing their teaching practices. The main purpose of the ISEP project is to provide teachers with professional development in interdisciplinary science inquiry. Teachers participate in a summer research experience and receive "wrap-around" services throughout the year which include the assignment of STEM graduate and undergraduate students in their schools. Nationally, there are countless examples of college students working in K-12 schools. This particular study aims to look at what exactly these students are doing in the partnership and how this may or may not help to facilitate interdisciplinary science inquiry teaching and learning in schools. It is hoped that findings from this research can help to assist researchers and educators in facilitating the successful establishment of university-school partnerships, Professional Learning Communities, and Communities of Practice. Specifically, the research questions are:

1.) How are university students' roles defined within the context of this school-university partnership?

2.) How may these roles facilitate interdisciplinary science inquiry teaching and learning in the schools?

Theoretical Framework

The communities of practice framework will be utilized as a lens to examine the findings, as it provides a way to examine groups of people informally bound together by shared expertise and passion for joint enterprise (Wenger, 1998). The framework is based on the theory that learning is a social endeavor and is particularly transformative when it involves membership in a community of practice. Communities of practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis (Wenger, McDermott, & Snyder 2002).

Wenger et al. (2002) argue that while communities of practice take on a variety of forms, they all share a basic structure and are a unique combination of three fundamental elements: a *domain of knowledge* which defines a set of issues; a *community of people* who care about this domain; and a *shared practice* that they are developing to be effective in this domain. When they function well together, these three elements make a community of practice an ideal knowledge structure – a social structure that can assume responsibility for developing and sharing knowledge. This study will use these three elements: *domain of knowledge, community of people,* and *shared practice* as a lens to examine the findings of the research.

Literature Review

This particular aspect of the ISEP project was modeled after the National Science Foundation 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.

STEM University Students

In their most recent evaluation of the GK-12 program (NSF, 2010), a majority of current and former fellows indicated that their GK-12 experience benefitted their ability to conduct various activities requiring communication, teaching, and teamwork skills. A majority of former fellows' faculty advisors also concurred that the GK-12 program helps fellows develop skills in these areas.

Besides their own assessment, several studies have also reported on the positive effects of the GK-12 program on STEM students. In one study (Thompson, Metzgar, & Collins, 2002), Graduate Teaching Fellows placed in secondary school science classrooms during the 2000 – 2001 academic year reported that they benefitted by developing an 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 fellows improved their communication skills and understood the value of linear conceptual development in science curricula and their ability to facilitate that as teachers. Laursen, Liston, Thiry, and Graf (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 faculty advisors as well as pre- and post-questionnaires completed by fellows 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), fellows reported improvements in confidence and ease of speaking while teaching audiences of all ages. GK-12 fellows 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). Huziak-Clark, Van Hook, Nurnberger-Haag, and Ballone-Duran, (2007) reported that fellows in their study learned communication skills to enable them to discuss complex ideas with others who do not have similar content knowledge.

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 et al. (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 RAISE (Revitalizing Achievement by Using Instrumentation in Science Education), 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.

Teachers

Teachers involved in the GK-12 program have reported numerous benefits as well. These include a.) increased STEM content knowledge (Gamse, Carter Smith, Parsad, Dreier, Neishi, Carney, Caswell, Breaux, McCall and Spader 2010; Laursen et al 2007; NSF, 2010), b.) a use of more effective pedagogical techniques (Gamse et al., 2010; Huziak-Clark et al., 2007; NSF, 2010), c.) greater access to STEM resources, (Gamse et al., 2010; Moskal, Skokan, Kosbar, Dean, Westland, Barker, Nguyen and Tafoya 2007; NSF, 2010) d.) greater confidence and preparedness to teach STEM concepts (Gamse et al., 2010; NSF, 2010; Stamp & O'Brien 2005), e.) increased technology instruction (Moskal et al. 2007), f.) an increase in the use of constructivist practices (Beamer, Van Sickle, Harrison, and Temple, 2008), g.) learned new ways to teach science (Laursen et al., 2007); h.) an increase in the number of real world and interdisciplinary examples presented during classroom instruction (Moskal et al., 2007); and i.) increased inquiry implementation (Gengarelly & Abrams 2009; Huziak-Clark et al., 2007).

In regards to increased inquiry implementation, Huziak-Clark et al. (2007), describe the Partnership for Reform through Inquiry in Science and Mathematics (PRISM) program which is a collaboration between graduate students in science or mathematics, classroom teachers, and university faculty. Graduate student fellows partner with classroom teachers for one to two years. The partnerships begin with a five week summer Inquiry Institute for both fellows and teacher partners. Then throughout the school year, the fellows and teacher partners work together for about 15 hours per week to develop, revise, and teach inquiry-based lessons in mathematics or science. Huziak-Clark et al. (2007), found that these teaching teams demonstrated effective use of inquiry and gained confidence in planning and implementing inquiry lessons.

Gengarelly and Abrams (2009) report on a GK-12 project named Partnerships for Research Opportunities to Benefit Education (PROBE). In PROBE, graduate fellows worked with one high school teacher 2 days per week for one academic year to introduce inquiry-based instructional practices into local secondary school math and science classrooms. During the summer prior to the start of the school year, the fellows and the cooperating teachers attended a weeklong workshop, where they worked to develop a common language around the definition of inquiry-based teaching and began thinking about where inquiry could be added within the teachers' curriculum. A common approach used by some of the fellow-teacher teams, especially initially, was the rewriting of existing labs in order to make the exercise more inquiry-based. As the PROBE program progressed, the fellow-teacher teams continued to implement a variety of types and levels of inquiry. By the end of the academic year, the majority of the classrooms experienced guided inquiry and many experienced open inquiry.

The Baumgartner, Duncan, Handler, and Yalap article (2009) was not as promising in regards to scientific inquiry. Baumgartner et al. reported on the GK-12 program at the Ecology, Evolution, and Conservation Biology program at the University of Hawai'i-Manoa (UHM). Graduate fellows are partnered with teachers or education outreach professionals to build individualized projects. The fellows also participate in an education seminar course offered by the Curriculum Research & Development Group (CRDG) at UHM. The seminar course provides background training in certain pedagogical research and teaching techniques, particularly scientific inquiry teaching strategies. Under the supervision of project organizers, fellows planned an 8 day workshop and were instructed to include potential activities intended to share the scientific inquiry teaching skills they had been developing and practicing in their projects. They planned the workshop format in two phases: 1.) an initial series of field trips to sites of environmental interest around Palau and 2.) a series of concept and skill-building activities in a classroom setting. The second phase also contained embedded opportunities for the teachers, assisted by the fellows, to develop an inquiry-based project for their K-12 students in partnership with local scientists. At the conclusion of the experience, teachers did not report significant gains in understanding scientific inquiry. However, the teachers' experience with the instructional models was positively received and they reported utilizing workshop components in their classrooms, which indicated at last a small shift in thinking about the best ways to conduct science education. The researchers argue that if teachers are to gain a more thorough understanding of scientific inquiry as a teaching strategy, and of the importance of using that strategy, they need to be exposed to scientific inquiry theory and have a chance to explore the nature of science more extensively than occurred in this workshop.

The ISEP program being analyzed in the current research is unique in that it includes both graduate and undergraduate students who play different roles in the schools, but are tasked with facilitating interdisciplinary science inquiry teaching and learning in their placements. The partnership was designed to take a mentoring approach to teacher professional development by creating Professional Learning Communities (PLCs) 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. This approach is meant to aid the teachers and students in the schools, as well as the STEM students who are also learning science communication skills.

There was not a prescribed formula as to how these students would be facilitating interdisciplinary science inquiry teaching and learning. Therefore, this research looks to find out what roles the students are taking on in the schools and to what extent their roles may or may not be facilitating interdisciplinary science inquiry. It is hoped that findings from this research can help to assist researchers and educators in facilitating the successful establishment of university-school partnerships, Professional Learning Communities (PLCs), and Communities of Practice (CoPs)

Design of the Study

A case study research design was used in the current study. According to Creswell (2007), case study research is a qualitative approach in which an investigator explores a case or cases over time, through detailed, in-depth data collection involving multiple sources of information and reports a case description and case based themes. This particular approach is most appropriate because the purpose of the research is to provide an in depth understanding of the interactions of STEM students and teachers that are members of a university-school partnership. The university students and teachers were for the most part left to their own devices to decide how the students would be utilized in the schools and the roles that they would play. A case study design will allow us to take a thorough, detailed look into how the participants navigated their collaborations.

Context and Participants

The present study took place within the context of the ISEP project. The ISEP project targets middle and high school science and technology learning and is located in the northeastern region of the United States. The collaboration is a rather large one; its core partners include two institutions of higher education and twelve schools, all located within one urban public school district. 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 ten colleges and universities (including the core partners) along with over 70 service agencies, and a district parent coordinating committee. At the time of the data collection, the partnership was in the first and second years of the operational phase.

The partnership is funded by the NSF as part of its MSP program. It was designed to target the middle school experiences of students in science and engineering as they transition to high school. The project emphasis is on teacher professional development with a focus 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 Professional Learning Communities (PLCs) 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.

The program aims 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. 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 six to 12 will benefit from the classroom materials and related activities that are generated annually.

Mentoring is another large component that the partnership aims to utilize. 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 the 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. Science teachers in the participating schools, as well as university students assigned to the schools will be the participants in this study.

<Insert Figure 1 About Here>

<Insert Figure 2 About Here>

Data Collection & Analysis

Data were collected from multiple resources throughout the 2011 – 2012 and 2012 – 2013 academic school years, which were the first and second years of partnership implementation. Data included interviews, observations, and the collection of relevant artifacts. This data was analyzed for codes and themes with respect to answering the research questions. In addition, surveys were given to all of the university students involved in the partnership.

Interviews

Semi-structured, face-to-face interviews were conducted with teachers, PhD students, and undergraduate students involved in ISEP. Interviews were conducted at times and locations mutually agreed upon by one of the authors and study participants. With the interviewees' permission, interviews were audio recorded and transcribed to ensure that the perspectives of these teachers and students informed the research. The interview questions for the teachers, PhD students, and undergraduate students varied, as each group was asked to elaborate on their particular role in the partnership. However, the main goal of all of the interviews was for the participants to elaborate on what the STEM students were doing in the schools, and how those actions may or may not help to facilitate ISI teaching and learning. These interviews provided rich data and allowed us to understand their thinking, reasoning, beliefs, and insight into how the experience was unfolding for the teachers and STEM students.

Observations

In order to give context to the information related in the interviews, numerous observations were conducted throughout both academic school years and the summer. These observations were conducted in the middle and high school classrooms where STEM students were present, at after-school science clubs and science nights where STEM students were involved, at PLC meetings that involved STEM students, throughout a college seminar course intended to give STEM students support throughout their experience, and in summer research experiences that involved STEM students. By observing the STEM students and the teachers at work in the various components of the partnership, we gained a better understanding of the context in which they were working. 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, “freebies” given away at after-school activities, and large pieces of paper where undergraduates worked together to reflect on their experiences in the schools, and teachers reflected on how STEM students may contribute to their ISI teaching. In addition, PLC meeting feedback was collected and analyzed.

Relevant documents

Relevant documents pertaining to the partnership were collected throughout the 2011-2012 and 2012 – 2013 school years. All undergraduate students involved in the partnership submitted at least ten 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. Teacher applications explaining why they wanted to be involved in the partnership were collected as well.

Surveys

Surveys were given to STEM students during the 2011-2012 and 2012 - 2013 school years. It included questions about their preparation prior to going into the schools, experiences in the schools, perceived values of the partnership, self-efficacy in communicating science, and their background. Descriptive statistics, specifically means and medians, were calculated on the surveys to illuminate specific details particularly about what these students were doing in the schools.

A team of researchers (three for the first year and six for the second year) met weekly to discuss data collection efforts, interpretation and analysis of findings, and plans for the focus of future data collection activities. Data analysis activities began simultaneously with the data collection, as the researchers started to follow patterns and make meaning of the data during the data collection process. For the purposes of confidentiality, pseudonyms are used for all school, person, and place names.

Findings

The Role of STEM Students in the Partnership

There are a combination of both graduate PhD students and undergraduate students involved in the partnership. The graduate students are nominated by department chairs and program leaders, and then are chosen based on their research expertise, K-12 experience, financial need, and how well their skill set or expertise matched the needs of the school. As for the undergraduate students, a seminar course is promoted by their advisors and the students sign up for course credit. If they would like to continue after the semester is over, they can do so for internship credit and then for a stipend.

Working in the schools. There was not a prescribed formula as to what exactly the university students would be doing in the schools, as the needs were different in all of the settings. Therefore, the first research question set out to find what roles these students were fulfilling in the schools. Surveys were given to all students to find out exactly what types of activities they were engaged in. Table 1 presents the descriptive statistics of activities engaged by students.

<Insert Table 1 About Here>

From Table 1, we can see that the most common experiences that the students cited as having 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 the schools, it was 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 kids with their assignments, labs, and projects, as well as tutoring one-on-one. University students also tutored and aided students working in small groups. One teacher explains the benefit of this when asked about how the university students might contribute to his teaching,

> It is huge. I have a philosophy that if you have a body in my room, I need that body to be involved…so it might be sit down next to somebody and help them take notes, but most importantly I try to have any lesson that I'm doing have the ability to break it into a group and if I can, get more groups, and if I have 20 students and I have four adults I have 5-5-5, that's good. If I have six adults, that's better. I can break them into threes and fours. What that allows me is at least I know that in every group I have somebody that knows what they're talking about.
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> *Chris, High School Science Teacher*

That same teacher also mentions how the students in his room contribute by finding good quality resources for students to examine on a topic, rather than having them do a Google search.

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:

> 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.
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> *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 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 or clubs where they primarily worked with students in small groups, or did demonstrations in an after-school science night for students and parents. Additionally, some of the students helped to chaperone field trips or school activities, and some aided the teachers in finding resources such as science articles or websites.

While, like the undergraduate students, the graduate students primarily worked with students one-on-one or in small groups, besides that, in their interviews they described creating labs and presentations for the students. They were also 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 helping in small groups and doing the administrative tasks, the roles of the graduate students varied in the schools. One school was very focused on developing curriculum, so the graduate student helped with that. Several students were focused on bringing resources into the school. For example, one student set up a fish tank in the classroom so that it would "look more like a biology lab," she was growing plants so that the students could use them in an experiment, and she had set up a greenhouse to try to stir up some interest in a horticulture club. Another student, who was surprised that the school didn't have a recycling program, took the initiative to help bring one into the school.

Several graduate students also had developed labs and activities that either they or the teachers implemented, they could be found organizing or participating in after school science clubs and activities where they worked with students in small groups, or they did science demonstrations for students and parents at science nights. Several graduate students also coordinated field trip experiences for the students and arranged for guest speakers to speak to the students.

Facilitating summer research. While working in the schools was the primary task of the STEM students, the graduate students could also be found helping to facilitate teachers' summer research experiences and contributing to professional learning community meetings. The objective of the summer research component was for teachers to work alongside scientists at the university and in the field. The STEM graduate students often played an active role in these experiences, sometimes engaging with teachers more often than the host faculty at the university. Much like the work in the schools, there was not a prescription as to what exactly the summer research entailed. It was very much left up to the researchers, graduate students, and teachers to navigate. Also, while some teachers were paired with the same STEM students that would be assigned to their schools in the fall, other teachers were paired with different STEM students that they would not see in their schools once the school year started. Therefore, as was the case of their work in the schools, there was variation as to what types of work these graduate students did over the summer. For example one teacher Shauna, explained that her summer research experience was more observational than "hands-on" and that she spent her days watching Dave, a graduate student do his research and applications. When asked about his role in her summer research, she mentions,

> I don't think he changed anything that he does. I think he just went there and did his research the way he always does and I was more of an observer. I don't think he really knew what to do with me honestly.

However, that case was not the norm. Most of the graduate students were found showing the teachers how to use the equipment in the lab, how to characterize various samples that they took, they answered teacher questions, and some developed the labs or activities for the teachers to participate in.

Professional learning communities. The overarching goal of the professional learning communities (PLCs) in ISEP are to facilitate opportunities for various stakeholder groups to leverage the experiences, opportunities and resources afforded by the ISEP grant toward maximal student learning and growth. The grant has a variety of different PLC meeting formats. For example, some are for parents, some are for university students, and some are for both university faculty and students as well as administrators and teachers from the local school district. It is the data from these university/school PLC meetings that are included in this research.

The first professional learning community meeting for teachers and university students was held in August, after the summer research was completed, but before the start of the school year. This PLC was focused on those participants involved in the environmental cluster of research over the summer. Thirty-three people, both from the school district and the university were invited to this meeting, which was actually held on two different days to maximize attendance. The meeting was said to be mandatory, but there were several individuals from the participating schools and from the university that were absent. Eighteen individuals were invited from the school district (both administrators and teachers), and fifteen from the university (both professors and graduate assistants that worked with teachers over the summer). Of the eighteen that were invited from the local school district, ten teachers attended and of the fifteen invited from the university, nine different people attended. All of these were university STEM students (three of which attended both meetings), and one was a faculty member who worked with the teachers over the summer. The meeting focused on what went well with the summer research, what challenges were had, and how the teachers might implement their summer research during the school year. According to the participants at the PLC meetings, the major things that went well were the cross-collaboration between teachers at different schools, and the availability of the lab, resources, and faculty. The challenges that were mainly cited were that the research was really broad and by the time they really got focused on a research question, the summer was over, and that the equipment used over the summer would not be available to their students during the school year. Something that was cited as both a positive and a negative was the flexibility of the summer research. Some felt that it needed more direction, where others enjoyed the freedom to let their research morph into whatever fit best for them. As for implementation, one participant cited that the local nature preserve was going to label certain areas as "Sampling Areas" so that all schools can take samples throughout the year. Another teacher explained that her students have trouble understanding ions. So, they did a number of tests and developed two labs regarding ions. Then, they went to previous state exams and pulled questions regarding ions to ensure that these questions were being addressed. Another teacher expressed that they now have four activities to implement with students in their school learning garden.

At the second PLC meeting, involving both school and university participants, ninety-eight people were invited. The e-mail that went out did not specify whether this PLC was mandatory or not. However, it did say that the summer "Environmental Cluster" individuals will be convening, but that all ISEP teachers were invited to attend. The meeting was planned by an ISEP graduate student. Two university professors presented at the meeting, seven teachers were in attendance, and five ISEP graduate students were in attendance.

The presentation was focused on Fluorescence Microscopy and its advantages and disadvantages. It was mostly lecture based and the professors explained that while once cost prohibitive, that cost has gone with the advent of LED excitation sources. However, at the end the presenters asked if anyone wanted to "tinker with the software" and put some things under the microscope. At this point several informal conversations occurred between the presenters, teachers, and graduate students. For example, the presentation was taking place in the classroom of a teacher who had created an aquaponics system for his summer research. That teacher told some participants about the project and two other teachers and one graduate student gave him suggestions as to how he can more fully implement the system in his classroom. Another graduate student told a story about an aquaponics system that he built himself.

After the event, the graduate student who planned the PLC meeting was asked to give feedback on how he thought it went and the teachers filled out evaluation forms. The graduate student felt that overall the event was a success – that there was a good mix of attendees between teachers, graduate students, and UB faculty. However, he felt that it would be good in the future to have a mechanism built into the agenda to facilitate more input and discussion from the attendees. For example, they should be asked to provide upfront a couple thoughts about what they hope to get out of this and how they might relate it to similar initiatives even if they are not directly interested in the specific topic being presented.

The feedback from the teachers mainly focused on the practicality of bringing this information into their classrooms. For example, in their suggestions they wrote, *"I would like to see more 'how-to' demonstrations; how to set- up experiments in different subject areas."* and

"*Better idea of the agenda, what the goals are, and emphasis on participants bringing their own questions for application in their schools."*

Facilitating Interdisciplinary Science Inquiry Teaching and Learning

In looking at what the university students are doing in the schools, during the summer research, and at PLC meetings, one can see that there is a wide range of levels of participation. Therefore, it is no surprise that there is also variation in the amount of collaboration and facilitation of interdisciplinary science inquiry teaching and learning going on in the schools. In looking at these relationships between university students, teachers, and their classrooms, these relationships can be categorized into three main facilitation levels: Collaborative, Supportive, and Independent.

STEM students as collaborators. When looking at the relationships that were truly transformative, it was in the classrooms that involved the graduate students rather than the undergraduate students. Teachers in these relationships were observed and spoke about actually changing their curriculum and teaching practices because of the access they had to the content expertise of the graduate students. These are the teachers that spoke about how they would not be able to do certain things, were it not for the facilitation of these STEM students.

One example is at North Shore Elementary School. The liaison to the partnership, or coordinating teacher, Kathy, is focused on making her students' classroom experiences more meaningful and authentic in terms of practicing science as well as making her current curriculum better connected to their lives both inside and outside of school. To that end, one component of her summer research was to create a unit on cholera for her middle school students, which was based in the community that the school was located in. She used a similar SEPUP unit as a guide, but recreated it to take place in a location that the students are familiar with. Kathy feels strongly that SEPUP, an issue-oriented science curriculum, can be used to teach students about interdisciplinary science inquiry. The problem with SEPUP, however is that not all schools have the funds to purchase the curriculum and corresponding supplies.

At an observation in one of Kathy's classes, Phil, a geography graduate student was teaching a lesson within Kathy's cholera unit. One of the main problems that students were faced with within the unit was, where was the illness coming from? How did it spread? Phil was explaining to the students how today, we can use GIS to help us solve problems such as these. He showed students the location of a water pump, and also plotted how many deaths there were surrounding that water pump. He explained that someone had an idea to close the pump, that possibly it was the pump causing the epidemic. Phil explained that this would be considered a hypothesis, and that if someone had a different idea based on the data being shown on GIS, that it would be considered an alternative hypothesis. He then asked the students if any of them had an alternative hypothesis based on the GIS data. Phil and the students continued the lesson in much the same way, and Kathy was found walking around the room, correcting off-task students, and making supplementary comments into Phil's lesson whenever she felt it was necessary.

After the lesson, Kathy, Phil, Gary (another STEM student assigned to the school), and Tony (another middle school science teacher) all joined together to discuss the details of another project that they are all working on. This project is intended to be a long-term project for 6^{th} through 8^{th} grades regarding water testing. Gary had created a rough outline of what needs to be done to implement this project and the others were contributing to his outline. At the end of the meeting, he had told Tony and Kathy that he had secured funds through ISEP to purchase the SEPUP program at their school, which made Kathy and Tony very happy.

Not long after the observation, Kathy and Tony were both interviewed regarding their experiences in the ISEP program thus far. When asked about the graduate students assigned to her school, Kathy, a middle school science teacher mentions, “they are really bringing in ideas like GIS that we could not talk about, as we didn’t even know about, but we are learning from them.” Tony, a science teacher at the same school mentions,

> It is nice to be able to bring someone in who knows much more or is much more passionate about that particular slice of what they do. To see an interest in a certain skill set is a great exposure for the kids…they have helped us in expanding our expectations for certain activities.

Phil, the graduate student working with Kathy and Tony was also interviewed about his role in the ISEP program. He refers to bringing in knowledge about GIS when he says,

> …and it involves a lot of troubleshooting so it's very much like we're very much there to support them and you know, if there's concepts that they don't understand, we’re the ones who figure out what needs to happen. You know especially with things a good example being GIS, they don't know much about that, but I'm happy to explain and talk with the students at their level that they can understand because the teachers are also benefiting from that.

In addition to what is being done in class, the Graduate and Undergraduate students have helped to implement an after-school science program. At one session they assisted the students in understanding rate. They took the students out into the hall and asked them to hypothesize what they thought would go down a ramp faster: a ping-pong ball or a metal marble. Then they helped the students to conduct the experiment, convert their data into the rate formula, and divide it in order to get an answer in terms of feet per second. At another session, the university students led a lesson in blood-typing. After explaining different blood types and how one could go about finding theirs out using antigens, they used a lab kit to perform fake blood typing.

When asked about the benefits of the after-school program, one of the graduate students explains that he has observed students in class who, when doing something related to the after-school program express, “Oh, we did this! I know how to do this!” and often help the other students understand it as well. He feels that this peer helping peers, as well as the repetition in practicing skills is a good way for students to learn.

STEM students as support. Not all of the teachers in ISEP felt that they had benefitted as much from the university students as the teachers at North Shore Elementary. For most of the teachers, their teaching practices or curriculum did not change to incorporate the expertise of the university students. Rather, the students acted more in the role of a “teacher aide;” walking around the room, passing out materials, answering questions, etc. These teachers referred to the students as an “extra set of hands” or “a help” in the classroom. While the STEM students were seen as a great help because they could walk around the room and work with students in smaller groups, the teachers’ lessons were not transformed in a such a way that they were at North Shore Elementary School.

One example is Brandon at Technical High School. Brandon teaches in the Career and Technical Education (CTE) Engineering Technology program at his school. In his summer research proposal, he stated that he wanted to develop curriculum for his students to apply knowledge of physics in his CTE classroom to develop devices such as towers, catapults, magnetically levitating cars, etc. to compete in Science Olympiad and Tech Wars competitions. During the summer he worked with two other teachers at his school: John, another CTE teacher and Tim, a Physics teacher. The three worked with a Physics professor and his graduate assistant (who was his personal graduate assistant, not an ISEP graduate assistant). Most of their time was spent in the machine shop, as they were working on three main Science Olympiad events: magnetic levitation, elastic launch glider, and the boomilever. They explained that their students will create their own models in class, but over the summer they wanted to go through the process of building these things themselves, so that they can better explain the process and the physics behind it. During a summer observation, the three were putting the finishing touches on their elastic launch gliders and boomilevers and were testing them. Later, Brandon had asked for a copy of the researcher's video so that he could use the footage to show his students.

Once the school year began, Brandon notified the researchers of when he would be implementing the boomilever project in his classroom. During an observation of his classroom, his students, who had worked in groups of two or three, were testing their boomilevers. The class began with Brandon telling the students the order in which they will go up for testing. He also reminded them that they had a homework assignment at the end of the week in which the students were asked to reflect on: 1.) Was today's boomilever an improvement over your last one as planned?; 2.) What did you learn from the process?; 3.) What did you do well?; 4.) What did you do not so well? At the front of the room, Brandon had put up a setup where students adjusted their boomilevers and a bucket. Once adjusted, the students put sand in the bucket and observed how long the boomilever could withstand the weight. Lee, the graduate STEM student in the class was taking before and after pictures of the students' boomilevers. After the boomilever broke, Brandon calculated and announced the boomilever efficiency.

After the classroom observation, Brandon was interviewed about his experiences in ISEP. When asked about how the STEM student assigned to his room may have contributed to his teaching or project goals, he mentioned that Lee was helpful when he was in the room. He gave the example that sometimes he has 24 students in his room doing all different things, and he was typically by himself. However, Lee was able to go around and had the students see different things that they might not see on his own; having two of them is twice as good as having one of them in the room. Brandon was then asked if there were any suggestions for improvement for participating STEM students in his classroom. His suggestion would be to pair them up better to their field of expertise, as Lee is a chemistry major and Brandon did not use a lot of chemistry in his classroom.

Lee was also interviewed after the observation and was asked if he thought his work in the grant helped to increase teachers' interdisciplinary science inquiry knowledge. He thought that he had, and cited the example that he helped both in Brandon's classroom as well as John's computer-aided design (CAD) course. So kids could use CAD to draw the structure first, and then get the blueprint for Brandon's class to build and test the structure efficiency.

STEM students as non-essentials. When asked about the contribution of the STEM students in their classrooms, none of the teachers expressed that they were "no help" or a "hindrance". As explained above, most of the teachers felt that they did help in some way, at least by helping to keep students on task. However several of the STEM students, particularly the undergraduate students during the first year of the partnership expressed feeling as if they weren't doing much in the schools. When these students were asked if there was anything that went poorly, the most common answers cited were centered upon the fact that not all teachers fully utilized them in their rooms. They described sitting in the back of the room during lectures and watching films. For example, the following is from an undergraduate student's journal:

> 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 utilize students during the first year, did not get assigned students the second year.

Discussion and Conclusions

As demonstrated in the findings section, there was great variation in the degree to which university students facilitated interdisciplinary science inquiry teaching and learning in schools. To examine why this might be the case, we looked at the community of practice framework proposed by Wenger et al. (2002). Wenger et al. (2002) argue that while communities of practice take on a variety of forms, they all share a basic structure and are a unique combination of three fundamental elements: a *domain of knowledge* which defines a set of issues; a *community of people* who care about this domain; and the *shared practice* that they are developing to be effective in this domain. When they function well together, these three elements make a community of practice an ideal knowledge structure – a social structure that can assume responsibility for developing and sharing knowledge.

Domain

Wenger, McDermott, and Snyder (2002) describe the concept of domain as the following: "The domain creates a common ground and a sense of common identity. The domain inspires members to contribute and participate, guides their learning, and gives meaning to their actions" (p. 28). In terms of the university students and teachers involved in ISEP, it was clear that those involved in ISEP wanted to help students. However, what was not made explicit was that conducting interdisciplinary science inquiry was the way to do that. One of main focuses of ISEP is to extend interdisciplinary inquiry based science and engineering to the schools, and to increase the interdisciplinary science inquiry knowledge of teachers. However, when teachers and STEM students were asked if their experiences in ISEP contributed to teachers' interdisciplinary science inquiry skills, most felt that it "indirectly did" or "did in a way". Rarely, did any of the teachers or STEM students interviewed mention that promoting interdisciplinary science inquiry was one of their goals for the partnership. Instead, their perceptions ranged from the goals of the program being to improve students' well-being, to making science fun for them, to prepare them for a career in science, or to bring meaningful science activities into the classroom. If interdisciplinary science inquiry is one of the main goals of the program, that domain should be made more explicit to the teachers as well as the STEM students who are there to help facilitate that knowledge.

Community

According to Wenger et al., (2002): "The community creates the social fabric of learning. A strong community fosters interactions and relationships based on mutual respect and trust. It encourages a willingness to share ideas, expose one's ignorance, ask difficult questions, and listen carefully" (p. 28).

There are several components to the ISEP program aimed in part to help STEM students and teachers build a sense of community that will help foster interdisciplinary science inquiry in the schools. These include graduate students working with teachers over the summer, graduate and undergraduate students working in the schools, and graduate students and teachers attending professional learning community meetings.

When it comes to the element of community, many teachers explained that the university students are a big help in their classrooms. They aid them in classroom management, tutoring students, and can also be found bringing their expertise into the classroom and in after school activities. However, several described the STEM students in their classrooms as well as in their summer research as not being the "perfect fit" or an "off pairing" because the students were not majoring in their specific content area. This could be related to the fact that the teachers and STEM students are not yet working under the domain of interdisciplinary science inquiry, because if they were working under that domain the teachers might embrace the opportunity to work with someone who is specializing in another content area, rather than to see them as not fitting in with their content.

Practice

Wenger et al., (2002) describe practice as "a set of frameworks, ideas, tools, information, styles, language, stories, and documents that community members share…The practice is the specific knowledge the community develops, shares, and maintains" (p. 29).

One of the main goals of this partnership is for the STEM students to help the teachers to develop interdisciplinary science inquiry knowledge and skills so that they can practice interdisciplinary science inquiry in their classrooms. As we can see from the profiles above, there was wide variation in classroom practices.

STEM students were asked to comment on whether or not they think they have been helpful in increasing teachers' interdisciplinary science inquiry knowledge. For most part, they did not feel that they played a direct role in increasing teachers' interdisciplinary science inquiry knowledge. Below, two students mention that they feel they played an "indirect" role.

> I think not directly, but indirectly we have. For presenting or creating a lesson, or we're working on presenting some sort of activity, there is a need to present context associated with that. You know, why do we care about water quality? Well, water quality has a lot to do with everything around us. And then we can get into topics like what affects water quality, has water quality changed? And I think it might start out at first as this indirect way, but it becomes more and more an essential component of our activities as we start to realize that especially with issue-oriented science education, you need to discuss the context to understand why you need these kinds of tools to understand what's happening in the system. So I think it begins as indirect and goes to direct when we get more hands-on science work.

> I think maybe in like an indirect way. I think maybe for this sort of thing is like that when the teacher just asks about something, something I do, or sort of like brings me into the conversation they're already having in the classroom, but I don't know, I feel like it's more of an indirect sort of thing. I don't know.

At a teacher professional development session, teachers were asked to get into groups and discuss how different components of the ISEP project help them to do interdisciplinary science inquiry in their classrooms. When it came to the PhD students, these teachers primarily mentioned that they help to create and conduct lessons and labs. They also help students to understand and learn new methods, and they help with content development and material support. As for the undergraduate students, they felt they primarily assisted interdisciplinary science inquiry by focusing on after-school programs.

Implications

After looking at the data from this study one must ask, how can we move all teachers and STEM students toward the "collaborative" category? Also, how can we help to make school-university partnerships a true community of practice, where all participants are developing and sharing interdisciplinary science inquiry knowledge? In looking at the community of practice framework, it is clear that the domain of interdisciplinary science inquiry must be made more explicit. If this partnership believes that doing interdisciplinary science inquiry in schools is the way to improve science learning in students, then we suggest that it must be made explicit to all participants in the partnership: the teachers, the faculty working with them over the summer, as well as the university students going into the schools. While the participants in this study felt that their goal was to "help kids", they were less clear on the fact that they were supposed to be doing so under the domain of interdisciplinary science inquiry. It is suggested that researchers and educators facilitating school-university partnerships make the domain explicit to all of the stakeholders in the partnership.

The partnership can also do better by focusing more on the concept of community. There were community-building structures built into the partnership: professional learning communities, mentoring, the university working with teachers, however these structures are implemented sporadically. Teachers and university students are unclear as to whether they are mandatory or not, and even when it is said that they are, many do not attend. We suggest that the expectations for participation be made more clear, as well as the purpose and goals for such activities.

Finally, since this partnership is nearing completion of year two they have some interdisciplinary science inquiry practices that can be showcased to all future participants of the partnership. One of the reasons why there was such variation in collaboration practices is because teachers and university students were left to navigate the summer research experience and school practices on their own. The PhD students working full time in the schools had no training prior to entering the classroom. They were left to negotiate for themselves as to what the best way to teach science was, and then try to facilitate that in the schools. It is suggested that researchers and educators facilitating school-university partnerships ensure that stakeholders going into schools have at least some type of training prior to entering the classroom. It is also suggested that participants be shown exemplars of teachers, university students, and university professors working in a true community of practice by utilizing the collaborative structures built within the partnership.

Limitations

The main limitation of this study was that the participants that were observed and interviewed were selected due to their willingness to participate. While all of the teachers and STEM students involved in ISEP were contacted, not all of them agreed to be interviewed and observed. Also, because the PLC component of the partnership was implemented later than most of the other components, only two PLC meetings were analyzed for this study. However, despite these limitations, we do believe this study provides insight as to improvements that need to be made as the project moves into the next year of implementation.

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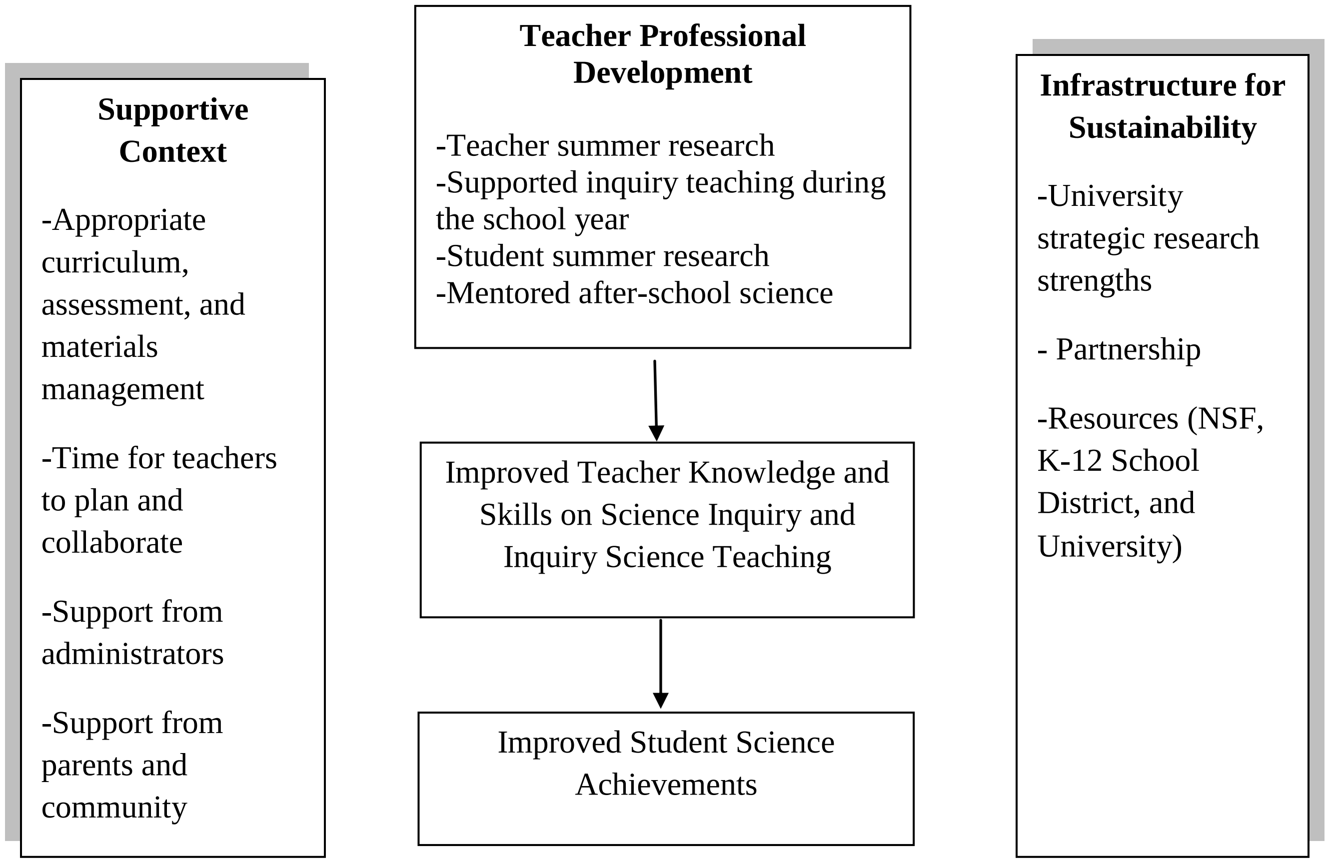
Figure 1: Conceptual framework for the partnership



Source: Project Summary submitted to the National Science Foundation

Figure 2: Major activities to take place within the partnership

Teacher Professional Development - approximately fifty teachers partner with scientists from the university as well as community partners during the summer to conduct summer research

After-School Science - the creation of after-school and weekend science clubs designed to expand student inquiry learning opportunities, to be staffed by STEM PhD students

College Students in the Schools -the assignment of a full-time STEM PhD student and several part-time STEM undergraduate students to each school to support teacher implementation of interdisciplinary inquiry-based science instruction

Professional Learning Communities (PLCs)- the creation of expanded 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

Extended Learning Opportunities - field trips to the science museum and the university

Enrichment Opportunities - summer enrichment and university research internship programs for students.

Source: Project Summary submitted to the National Science Foundation

Table 1
Descriptive Statistics of Student Experiences in Schools (n=70)

Activity	Frequency (%)
Assisted teachers in teaching lessons	45 (64.3%)
Assisted teachers in conducting labs	53 (76%)
Developed science labs for class use	21 (30%)
Developed out-of-school science learning activities	10 (14.3%)
Led small group activities/discussions with students in class	51 (72.9%)
Led small group activities/discussions with students after school or during weekend	17 (24.3%)
Demonstrated scientific content, procedures, tools, or techniques to students	49 (70%)
Helped teachers find relevant resources (e.g., science activities)	24 (34.3%)
Presented lessons/lectures to students in class	20 (28.6%)
Tutored students after school or during weekends	7 (10%)
Other	4 (5.7%)