

Implementing Service-Learning Partnerships: Educating Scientists in the Present and for the Future

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ABSTRACT

The purpose of this research is to shed light on the power of partnerships between advanced college science students, K-8 students, teachers, and home-schooling parents. The pedagogical difficulties and educational opportunities of each population is explored via qualitative analysis, with an evaluation of the strengths gained by connecting the groups via a service-learning project. An emphasis on the active, discovery-based nature of science is paramount to the project, and the partnerships allowed for human development of young scientists in ways that are not always achievable through traditional academic experiences.

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INTRODUCTION

Science is anything but a dead subject. In teaching science, educators are increasingly moving toward active pedagogies where students engage with science as a way of understanding the world around us - including evidence, its limitations, and real-world problem solving (National Center for Science and Civic Engagement; Next Generation Science Standards). An increase in broad scientific literacy in K-16 education is crucial for producing a public that can better understand the role of science in their lives (McDonald & Dominguez, 2005; Reynolds & Ahern-Dodson, 2010) and share in the empowerment that comes from using science as a tool to address humanitarian interests (Nair, 2011). Community-engaged projects in the sciences are an especially valuable method for helping students to reach deeper understanding of scientific content and for being included as members of the scientific community.

The field of service-learning in science education is still relatively new. Many scientists have long engaged in what is described as outreach: scientists participating in public science demonstrations, lectures, and the like. These activities, however, are largely disconnected from student learning. Over the past decade, science education reformers have called for a reconsideration of these missed opportunities through an alignment of community science with curricular learning (Moore, 2006; Ramaley & Haggett, 2005; Wiegand & Strait, 2000). Despite this call, research (Sherman & Macdonald, 2009) has shown that many students in STEM fields feel uncomfortable with the uncertainty involved in community-based work, while their professors frequently hold the belief that community projects are lacking in rigor. Scientists still have a ways to go in overcoming these biases.

In reality, studies have shown that the benefits of well-designed service-learning experiences in scientific coursework serve to amplify learning rather than detract from it (Santas, 2009). Higher

education especially has seen an emphasis on service-learning pedagogies as a way of strengthening teaching and learning by providing students the opportunity to connect classroom learning with real-world applications (Campus Compact; The National Task Force, 2012; Zlotkowski & Duffy, 2010). Whereas a major purpose of education in any discipline is to encourage critical thinking, students engaged in service-learning projects are often able to perform at high levels of thinking and action, and these skills persist long after college ends (Fitch, Steinke, & Hudson, 2013). A meta-analysis of service-learning pedagogy also indicates that its broad-based tenets reach beyond academic knowledge toward the affective domains of meaningful personal, social, and citizenship outcomes (Conway, Amel, & Gerwien, 2009). Based upon these theories and findings, service-learning seems promising for expanding students' scientific skills into the broader context of true scientific literacy.

The push for more active and approachable scientific learning is often problematic in K-12 education, however, when a child's sense of wonder about the world is replaced with high-stakes testing and the relegation of science to a list of facts and rules (Herbert, 2010). As teacher Doug Ronsberg writes in his poem "There's More to Teaching Science," teachers should "Encourage interactions so they share the things they know / to reason and defend the things they think their data shows" (Ronsberg, 2006). As the poem states, students need more interactions with others within a wide scientific community in order to share, reason, test, and interpret. A multitude of partnerships exist between scientists in higher education and budding scientists in the K-12 educational system (Caprio & Borgesen, 2001; Esson, Stevens-Truss, & Thomas, 2005; Hark, 2008; Laursen, Liston, Thiry, & Graf, 2007; Lesser, Dunne, & Faszewski, 2014; McDonnell, Ennis, & Shoemaker, 2011; Schon, Eitel, Bingaman, Miller, & Rittenburg, 2014). It is through building these partnerships between children and college students - and parents and teachers and

professors - that insights can be gleaned into the most impactful engaged pedagogies for the benefit of the full K-16 population.

A LOCAL PARTNERSHIP – MACON, GEORGIA AND MERCER UNIVERSITY

All of the aforementioned ideas and research were utilized in the redesign of a 400-level college biochemistry course at Mercer University. Seminal to the redesign was an American Society for Biochemistry and Molecular Biology (ASBMB) 2008 report showing that whereas biochemistry college curriculum prepares students for the professional field, it is “lacking in skills for personal and social responsibility” (p. 4). Science students in higher education are often excellent at demonstrating content knowledge, but often display unreflective thinking and/or an immature self-knowledge of why they are pursuing their chosen field of academic study (Goldberg & Coufal, 2009; Sharon, 2012). They do not frequently have the opportunity to engage with others as scientists and to determine what their role is and should be.

Mercer University’s mission statement is “to teach, to learn, to create, to discover, to inspire, to empower and to serve,” so community-engaged educational practices are ingrained within the institution. As part of ongoing professional development activities, I had an opportunity to meet several community partners and heard from local public school officials discussing the discouraging K-12 student assessment data for math and science. As a direct result of the troubled school system, a large number of Middle Georgia families have chosen home-schooling as the preferred option for their families, and, as discussed below, express several concerns about teaching science to their own children.

In thinking through these problems and discussing with others, a clear area of overlap emerged: college science students with a lack of off-campus learning opportunities and school children with a need for more engagement in science. In order to address the needs of both a subset of the

college student population and local school children, it was determined that the college biochemistry course would be revised to include service-learning. The college science students worked to design and deliver hands-on science experiments at several local elementary schools and middle schools and at workshop events for home-school children at the Museum of Arts and Sciences in Macon. The project continued over 4 years, during which qualitative data was collected and interpreted in order to better identify problem areas, to provide insights into effectiveness of the service-learning partnerships, and to distinguish the ways that these partnerships assist with science teaching and learning.

DEFINING AND ADDRESSING PROBLEMS IN K-16 SCIENCE EDUCATION

Research Methods

Ethics and Qualitative Research

The project was approved by the Mercer University Institutional Review Board as part of the Office of Research Compliance. All participants providing data had a chance to read an Informed Consent Form (ICF), ask questions, and gave permission via the ICF for their responses to be used in the research project.

The successes of the service-learning project described and analyzed within this chapter were highly dependent upon interpersonal interactions, and thus qualitative analysis was determined as the best research method. In qualitative analysis, the researcher aims to understand how people interpret their lives through the meanings ascribed to their thoughts, experiences, and emotions to get at the why and how of a social paradigm (Boeije, 2010; Denzin & Lincoln, 2005). The grounding framework for the project described herein is the interactive and integrative theory termed the *civic learning spiral* (Musil, 2009). The civic learning spiral attempts to combine six relational elements of human development: understanding of self, communities and cultures,

knowledge, skills, values, and public action. By applying the analytical lens of the civic learning spiral, it became possible to interpret students' growth in each of the discrete areas with an understanding of how the connections between the domains strengthened the holistic learning environment for all.

College Students and Demographics

Mercer University is a private institution with a total student population of around 8300, representing 12 colleges and schools. A majority of the undergraduate degrees (B.A. and B.S.) in the College of Liberal Arts are awarded in the scientific fields of biology, chemistry, and/or biochemistry and molecular biology. It is students in those three academic majors that would have the necessary prerequisite courses to enroll in the biochemistry laboratory class described herein.

The service-learning project ran for four years, with 41 total college students contributing to the work. The overall male-to-female ratio of the college students in the course was 38% male to 62% female. In terms of ethnicity, 56% of the students were Caucasian, 13% of Indian descent, 10% Asian, 8% Hispanic, 6% African American, 5% international students from Eastern Europe, and 2% of Middle Eastern descent.

Qualitative data on the service-learning project was collected from the college students at the end of each semester, via recorded and transcribed whole-class focus group interviews. The focus group interviews centered around five question prompts:

- What did you learn through your service-learning project?
- What were your impressions of service-learning prior to beginning the project?
- How did your experiences alter your impressions?
- How does the project fit within the biochemistry and molecular biology curriculum?
- What other comments would you like to provide that have not yet been covered?

Each focus group interview lasted for an average of 45 minutes. The focus group interviews allowed for a large degree of group interaction – determining where the students agreed upon key learning outcomes from the project and where they disagreed, in addition to which subjects generated the strongest perceptions of self-growth.

Teachers and Demographics

There were five teachers interviewed as part of the study, and they are provided code names to maintain anonymity. Each of the teachers is currently or has been a lead science teacher in an elementary or a middle school. The teachers were recruited via personal interactions: three of the teachers (Anne, Barbara, Christine) have been community partners for the service-learning project, one (Diane) is a former Mercer student who served with Teach for America for two years before moving to a high school chemistry teaching position, and the other (Eva) is a teacher and administrator in a middle school pre-engineering program. Their brief demographics are given in Table 1.

Table 1. Teacher Interviewee Demographics

Code Name: ¹	Science teaching experience (in years)	Highest degree earned
Anne	19	Ed.S. (educational specialist)
Barbara	23	M.S. (educational leadership and administration)
Christine	26	B.S. (biology)
Diane	3	M.Ed. (science education)
Eva	16	M.S. (educational technology)
¹ Each teacher is given a code name in order to protect anonymity. To provide context, these code names are used in the teacher qualitative analysis section.		

The teachers were all interviewed separately, with an average interview length of 40 minutes.

The interviews were all transcribed for coding purposes. The questions asked of the teachers are as follows:

- Please describe your major concerns about teaching in general.
- Please describe your major concerns about teaching in the area of science.
- How do you envision the ideal parent-teacher-student relationship for helping your students achieve learning goals?
- To what extent do your science students regularly engage in community-based or science in society projects? What do you think makes these most successful?

In addition to the qualitative questions, the teachers were asked to give input on the following possible learning objectives and learning activities for their students in the topic of learning science. The teachers discussed each item and how it may or may not fit within their teaching methods, giving each a high, medium, or low rating. (The analysis of their responses can be seen in Table 2 in a later section.)

Possible learning objectives:

- Meeting state science standards for grade-level
- Understanding how ideas from science help address real-world issues
- Understanding how ideas from science relate to other subjects studied
- Applying ideas from science to real-world issues
- Applying ideas from science to other subjects studied
- Identifying patterns in data
- Recognizing argument and evidence in scientific theories
- Recognizing argument and evidence in scientific data
- Developing enthusiasm for scientific subjects
- Developing enthusiasm for future scientific study
- Additional learning objectives:

Possible learning activities:

- Reading science textbooks
- Reading general science books (nonfiction)
- Reading general science books (fiction)
- Working problems from textbooks or workbooks
- Writing (journaling, essays, etc.) about science
- Demonstrations of laboratory experiments (i.e.-teacher demonstrates, students watch)
- Hands-on laboratory experiments (i.e.-students perform experiments)
- Museum exhibits
- Nature walks and/or outdoor activities
- Community-based or science in society projects

- Science-related clubs
- Additional activities:

Parents

The parents in the study were recruited from one of the home-school workshops that the college biochemistry students delivered at Macon's Museum of Arts & Sciences. The parents were asked the same 5 questions as those asked of the teachers, and were also asked to give their input on the same learning objectives and activities as described above. There were a total of 10 parents who provided data, which was collected anonymously via paper survey.

Coding and Data Analysis

Once acquired, the data for each interview group (college students, parents, teachers) was individually analyzed according to the qualitative methods recommended in the text *Analysis in Qualitative Research* (Boeije, 2010). The data was coded via an open coding strategy. This involved carefully reading the data, disassembling it, comparing the fragments, grouping into categories, and labeling with a descriptive code. The data was then resynthesized via continuous consideration to analyze the evolving relationships between the categories and the credibility between those relationships. The final step involved connecting the parts into major trends and insights that emerged across the study population, as highlighted and discussed in the following sections.

Teacher Perspectives: A Qualitative Analysis

Teachers' Areas of Concern in Science Education

Importance of Inquiry. The teachers interviewed all indicated that problem solving and critical thinking are crucial in the science classroom. However, inquiry-based teaching, and especially inquiry-based laboratory experiments, are a time-consuming pedagogy and are not implemented

as frequently as they should be. Christine stated that many of her teacher colleagues are used to “cookie cutter” classroom activities where everyone has to get the same five problems correct and there is no room for deviation from the status quo. With discovery-based activities, all of the students are working on different tasks, sometimes at different times, and this can create a seemingly more chaotic classroom environment.

Because there are so many interesting scientific concepts that teachers want or are expected to teach, they do not always have the time to devote to inquiry-based activities. Unforeseen schedule disruptions often mean that instructional time is cut, and time-intensive pedagogies are the first to go. Diane shared that her school (urban, Title I), had been on lock-down seven different times over the past school year, all of which created a large disruption to both the learning environment and the time she was able to spend with students on engaging activities. Barbara stated that for many teachers, the “curriculum is so overprescribed, to the week, to the day of what they teach, it doesn’t allow for the very nature of science to happen.” Good teachers who understand the importance of inquiry are often able to balance content coverage with individualized learning opportunities, but too often, the time allocated to these skills is deprioritized.

Students are Trained to Do What’s Easy. As discussed above, all of the teachers interviewed spoke at length about the importance of helping students work through figuring out problems and tasks. Yet, they also indicated that some students, especially older adolescents in middle school, were “so used to having things given to them that they don’t want to take the time to process through what they’re doing” (Diane). Many academic skills – math facts, sight words, and the like – are taught through constant reiteration until they become memorized and/or internalized and students are rewarded for achieving a basic knowledge of these facts. Yet, children are also

born creative, and “if you don’t use those skills, they start to taper off” (Barbara). The science teachers interviewed were concerned that creativity is missing from the classroom in general, and that “not getting what you want” (Christine) and “trying things that aren’t going to be successful” (Eva) are a major component of learning and of developing higher-order thinking skills.

Ingrained Misconceptions. Making sure that students understand accurate scientific information was of concern to the interviewees. Scientific misconceptions “passed on to them by society, by parents, by cartoons” (Anne) are very common to the students of the teachers interviewed.

Although they find it important to correct students’ thinking when these misconceptions arise, it is more difficult to make these adjustments if the misconception comes from what a parent or another teacher has told the student. Frequently, non-science teachers will perform demonstrations that are meant as models or simulations of actual scientific phenomena.

However, the models are not entirely realistic and the students don’t always understand their limits, which results in an incorrectly-held belief about a scientific topic. The teachers interviewed indicated that it is important to not only correct the misconception, but to also identify its source so that the students fully understand how to correct their own thinking.

Teachers’ Areas of Concern for Education in General

Cumbersome Standards and High-Stakes Testing. “You cannot pretend that there hasn’t been a huge negative impact of assessment that has narrowed the curriculum” (Anne). This quotation represents what every teacher discussed at length: the trade-off between emphasis on learning and emphasis on assessment. Over-testing was the major concern of all of the teachers interviewed. They all understand and appreciate that we need to have some system of evaluation

of student learning, but “somewhere along the lines, we’ve developed this high-stakes testing that judges a teacher’s efficacy and...[has] taken so much of what teaching *is* away” (Barbara).

The interviewed teachers were considerably concerned that a result of high-stakes testing is that certain academic content is only taught at each grade level if that specific content were to be evaluated via standardized test. “As a science teacher, I’m just horrified at the number of elementary schools where science instruction did not happen at all because it was not being tested” (Anne). Eva indicated that in her county, K-5 students are only taught 18 hours of science per academic year. The emphasis on math and reading at that level is understandable, but students are less likely to receive a holistic and broad education if the “reactionary education pendulum keeps swinging back and forth” (Anne).

One-size Fits All. Along with an increase in common standards and common assessments comes a standardization of pedagogy to the norm of what works for most students. It is difficult for teachers to often reach every student every day in the allotted time with the allotted resources, so they often stick with what they know or what is easiest. Diane recounted the expectation that all of the teachers in her team (i.e.-those who were all teaching physical science at the middle grades level at her school) give common assessments and that the status quo was to use multiple choice tests. Each teacher had approximately 140 students each day, so the choice of utilizing multiple-choice tests is understandable in order to manage the grading load. Diane, however, believes that multiple choice tests in science are “great for fast grading, but not for learning.” In order to use supplemental short answer and essay exams in her classroom – reinforcing the active learning content – she had to receive special permission from a school administrator, received only after she could strongly articulate the value.

Anne recounted that the narrowing of the curriculum further boosts a reliance upon lower-level thinking skills: defining, memorizing, reciting. She acknowledged that “as a teacher, it’s easier for me to just go over it” than it would be to “let the kids go truly deep.” However, she knows that letting the students engage in figuring their own way to a solution creates deeper learning and, in turn, higher overall knowledge acquisition and retention.

Christine also indicated a frustration with other teachers who just “want the child to do what *they* want the child to do.” Not all children can learn in a one-size-fits-all paradigm, so an emphasis on active learning and individual instruction to reach the outliers is crucial. As she says, “It is a little more challenging and difficult to create a curriculum that goes after that, but what’s your yield? What do you want? Somebody that can check the box, or somebody that can build an entirely new box?”

Home Life and History of Failing Schools. While those interviewed indicated that they possess some control over the learning environment in their own classrooms, they acknowledge that the hours students spend away from school can make or break a student’s success. Many children, especially in high-poverty school districts such as those in Middle Georgia, are frequently caregivers for younger brothers and sisters. Their teachers encourage them to spend time in activities such as reading to those younger children in order to reinforce their own literacy skills. Christine discussed having been out of the classroom for several years and upon returning, realized that the change in the nuclear family has greatly altered how children and families relate to education. She discussed the dichotomy of students who have parents who work with them at home and those who do not, saying, “I try to do a lot with them when I’m here, but if I didn’t have that undergirding at home, I recognize that I would not enjoy the same success.”

Anne recounted that some parents also have a difficult relationship with the school system. “Whether they’re consciously aware of it, or subconsciously aware of it...they are now putting their children in the very system that failed them.” The teachers need to ask for help from parents at home, but those parents might also have low reading levels or insecurities or baggage about “every horrible teacher that they had and every bad experience they had and every slight they feel” (Anne). Whereas students are always learning and always adapting, the at-home dynamic does not always provide a beneficial learning environment for every student.

Teachers’ Perspectives on Areas of Promise in Science Education

Science as Something You “Do.” The teachers in the study sometimes struggled with a multitude of concerns as detailed above, but they overwhelmingly supported the idea that science is an active and engaging pedagogy. They were all able to convey the fun and excitement that they and their students experienced through discovery and inquiry. They described the activities in their classrooms as “powerful” (Anne), “integrated” (Eva), and “tangible” (Christine) for their students. Christine described the joy of the light bulb moments of “I got it!” when a student was able to stick through a difficult task. She also told the story of a student comparing science at his old school, where “mostly we had to learn a lot of words,” to the new paradigm of active and engaged inquiry in her science classroom. Diane describes the experience of active learning in science in the following way: “With 40 middle school kids in a classroom, it sounds like it would be a nightmare. But it was actually my best way to manage the classroom – to do science with them. They knew that if they couldn’t behave, then lab day was over.” It was clear throughout the interviews that the teachers felt that the most effective way to help their students learn was to work on active experimentation and inquiry.

Teaching the Story of Discovery. Along with active learning, the teachers interviewed indicated a strong preference for teaching science in the context of discovery: anchoring what is known to what is not known and how new research leads to revision of old ideas. Christine said, “That whole journey of discovery and confusion and struggle is something missing from modern-day education because we want to make it so darn easy for them.” Students need to learn what is currently known in order to start discovering for themselves and to see themselves as scientists. Some even encourage their students to contribute to crowd-source science projects, websites, and databases in order to see that science is approachable for all. The teachers expressed a frustration, as previously discussed, with those who teach science as a series of facts to be memorized, and instead put an emphasis on science as a mechanism for “go[ing] after the truth” (Anne).

Making Science Relevant. The teachers strongly exhibited the belief that they should make science relevant for their student populations. This took a variety of formats, from community gardens for teaching elementary students that “food does not come from the Kroger” (Christine) to launching marshmallows in middle school as an exercise in understanding gun death (Diane). The teachers all recognize that making science relevant is “crucial for keeping students invested” (Barbara). Since not all students take multiple years of science in high school – and in some areas, many won’t even finish high school – the K-8 teachers in the study wanted to make the most impact on the science education of their students while they still have them.

Connecting student learning to real-world issues is especially relevant for environmental science education standards. Many schools have recycling programs, clubs, and/or education for their students, and when those students start learning about specific concepts such as pollution or conservation of mass, one teacher described it as “almost like teaching them how to breathe”

(Anne). The students learn best when their real-world knowledge intersects with the scientific foundations the teachers are trying to instill, and deeper learning is often a result.

Teachers Believe in their Students. A strong and respectful teacher-student relationship is optimal for student learning, and it was clear from the interviews that the teachers cared about and believed in their students. The teachers described much of their jobs as building the excitement for science and instilling the confidence in their students that they could use evidence to arrive at supported claims. Diane said, “A lot of the success had to do with how I responded. I would make them feel smart when they got something correct...The kids I had weren’t used to being treated with positive reinforcement.” Christine explained “I hope that I can spark something inextinguishable. [These students] are going to be our problem-solvers soon. We need these brains to be open.” The quotations from these teachers are representative of what the larger sample had to say. Although teaching is often a difficult profession, these teachers believe that what they are doing is valuable and worthwhile.

Science is a Community of Minds and Ideas. In teaching science as discovery, the teachers also place their students into the larger community of scientists. Many of the teachers mentioned the importance of teamwork both in their classrooms and in the professional scientific world, pushing their students to realize that “you’re not the only smart mind here” (Christine) and how to utilize the strengths of others to reach a shared goal.

A section below details the role that the Mercer college students played in working with and mentoring a K-8 population on inquiry-based science. The interviewees who were also community partners for the service-learning project discussed the interactions of the K-8 students and the college students as an indicator of the power of showing their students the scientific

community. Barbara said, “Oh, they think the [college students] are like demi-gods. They are everything that middle school students aspire to be. One of your biochemistry students can say something one time and the students will remember it the rest of the year, even if – God love her – their teacher had said it five.”

The teachers interviewed stressed that it is important to their students – especially students in urban or semi-urban Southern cities – to see the diversity of science. Frequent media portrayals of scientists bias students toward what they believe a scientist *does* and what a scientist *looks like*. If science is to make gains in minority communities, more role models (especially women and people of color) need to step up and be visible (Moore, 2006), and more scientists and science educators need to identify and confront their own bias (Cone, 2012). The college students involved in this project represented diversity of gender, ethnicity, and socioeconomic status, as previously discussed. The ability of the K-8 students to engage with a multicultural, multiracial college population was an important way to model the diversity that we wish to portray in the larger scientific community. Anne discussed this concept in her students’ minds as “...there were college kids here, and some of them looked like me, so I can go to college too.” The power of these small glimpses into diversity can help to deemphasize the negative micro-messages that students receive about who scientists are, and to help make them see science as approachable to all.

Parent Perspectives on Science Education with Their Home-Schooled Children

The parents surveyed represented households comprising a total of 30 children. The majority were ages 6-12 (67%), with a small number of households indicating children ages 5 & younger (13%) or ages 13-17 (20%). As the home-school science workshops were specifically geared toward elementary-age children, it is not surprising that this was the largest population seen. As

one parent indicated, “as children reach grade 5, science concepts no longer capture the imagination of the child.” Both the teachers and the parents surveyed believe in the importance of capturing and cultivating early affinity for science.

Whereas the parent surveys were collected on-site during one workshop day and follow-ups were not possible, the data acquired was not quite as rich qualitatively as the information obtained through other aspects of the study. There were, however, several statements and quotations from the parent population that were representative of all, and the data provided by the home-school parent population in the study gives some insights into the places where these parents share teachers’ perspectives and where they diverge. Table 2 includes information from both the teacher and the home-school parent data. The teachers’ major learning objectives involved helping their students to make connections between scientific concepts and the issues surrounding humans in society. Parents, however, repeatedly used the terms “understand the basics” or “to be exposed to” when indicating their learning objectives for their children. The

Table 2. Common Trends from Parents & Teachers

What are your main learning objectives for your students in the topic of science?		
	Teacher Priority	Parent Priority
Understanding how ideas from science help address real-world issues	Highest	Secondary
Applying ideas from science to real-world issues	Highest	Secondary
Understanding basic scientific concepts/exposure to ideas	n/a	Highest
Understanding how ideas from science relate to other subjects studied	Secondary	Highest
Applying ideas from science to other subjects studied	Secondary	Highest
Developing enthusiasm for future scientific study	Secondary	Highest
Developing enthusiasm for scientific subjects	Secondary	Secondary
Meeting state standards for grade-level	Secondary	Secondary
What types of activities seem to be the most successful to help your students learn scientific concepts?		
	Teacher Priority	Parent Priority
Hands-on laboratory experiments	Highest	Highest
Writing (journaling, essays, etc.) about science	Highest	Secondary
Nature walks and/or outdoor activities	Secondary	Secondary
Reading general science books (nonfiction)	Secondary	Secondary

professional teachers seemed more aware of the learning outcome language of the higher levels of Bloom's taxonomy (Anderson & Krathwohl, 2011), and were able to aim their pedagogies toward at the Apply, Analyze, and Evaluate high-level learning goals.

Another important insight is that the parents were concerned with getting their students interested in science and indicated that they struggle with keeping them interested. They rated very highly a desire to see students develop enthusiasm and relate scientific concepts to other subjects. For many of the parents, anchoring their science lessons to other subjects seemed to be their main strategy for combatting scientific apathy. The teachers did not seem to see a lack of enthusiasm for science as a problem in their own classrooms; as lead science teachers, they already possessed that enthusiasm and were able to convey it to their students, bringing them beyond a basic interest and toward more active and engaging learning. This disconnect was also apparent in the qualitative analysis with the parents, as one explained her perspectives in this way: "There are very few people who are enthusiastic about science. I think it is in large part due to the fact that so many of us had 'Ferris Bueller's' teacher who rattled dull facts off to the ceiling and gave us long lists of irrelevant terms to memorize for tests."

Based upon the previously discussed science teachers' penchant for active learning and the parents' desire for increased enthusiasm, it is not surprising that both groups indicated a strong preference for active, hands-on experiments for learning science, as also seen in Table 2. Both groups indicated that students learn the most about science when actively engaged in experiments. The parents surveyed worried about their home-school scientific curriculum because "there are limited opportunities that are age-appropriate for my children." Another parent stated that "science experiments get pushed to the side because of the energy and time

they require.” The parents also discussed the fact that lack of supplies, expensive scientific equipment, and “know-how” were obstacles to doing more hands-on science with their children.

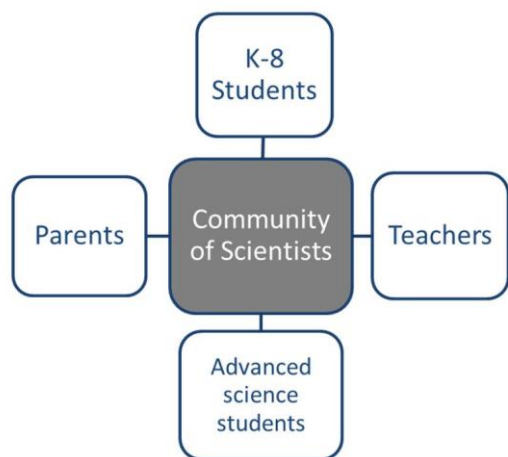
In analyzing qualitative data from both parents and teachers, there seems to be a fundamental divide between what both groups believe teaching science should entail and what it is in practice. The teachers see their roles in teaching scientific content to be in harmony with teaching science as a tool of discovery. The parents, however, felt that often scientific study is disconnected from “the amazing complexity of the world around us” and wish that “more science teachers...love what they do, are flexible enough to admit we don’t have all the answers, and are filled with an insatiable curiosity to learn more about how the world around us works.” It was clear that both groups have the same goal: teaching science as a living, evolving field rather than a list of facts and rules. The parents felt that many teachers they know are disengaged from this process. It should be noted that although the teachers in this survey were lead science teachers - engaged in coaching both students and other teachers toward more active ways of learning about science - they also faulted the current educational system for encouraging lower-order scientific learning through a variety of mechanisms.

Building a Community of Scientists in K-16 Education

The analyses from both teachers and parents point to the tension between how science is taught and how it is practiced. In one corner are students who have been rewarded for performing on standardized assessments, in another are science teachers who feel squeezed by trying to balance educational accountability with active pedagogies, and in another are parents who feel that their students are not gaining access to the opportunities they need for future success.

Missing from this paradigm is the scientist as practitioner. Many K-8 students see scientific concepts in the classroom, but never engage with those who call themselves scientists, thereby missing a valuable human component. To round out the corners, college students also have needs that are not always being met in their curricula. Advanced students have typically mastered content throughout their prescribed course of scientific study, but have not had an opportunity to communicate and apply their knowledge outside of the academy. By intentionally embedding college students into the parent-student-teacher paradigm, a stronger community of scholars is generated that helps to address the teaching and learning needs of all (Figure 1).

Figure 1. The community of scientists built as a result of this service-learning project



Addressing Gaps in Learning for College Science Students

Like many universities, Mercer University has seen great growth in the numbers of students interested in biosciences. Advanced students (300 level and beyond) are expected to gain experience with many lab techniques, keeping scientific lab notebooks, technical writing, and technical oral communication. However, it was found in teaching an advanced biochemistry laboratory over time that traditional experiments from lab manuals were duplicating skill sets that the students already possessed rather than providing an opportunity to explore something

novel. Furthermore, students seldom took intellectual ownership of their work. When given the opportunity to narrate their opinions on the lab experience, the major comment (>50%) was a frustration that the experiments did not go as expected, and that the experiments needed to be “worked out prior to trying them on students.” This type of feedback demonstrates the students viewing themselves as mere consumers of education rather than participants in it, and aligns well with some of the aforementioned concerns of both parents and teachers.

As the instructor for the advanced biochemistry laboratory students, I felt a need to revise the course pedagogies away from what techniques could be covered in the Mercer students’ allotted lab time to what major experiences were lacking in the college students’ education. Not only did those students need a chance to broaden their knowledge, engage with the other, communicate in non-technical terms, and think on their feet, they also needed to start taking responsibility for being curators of the discipline and speaking up as scientists for science. Some of the most effective service-learning projects balance a learning environment of student autonomy with competence and relatedness (Levesque-Bristol, Knapp, & Fisher, 2010), and opportunities for attaining these goals were highly desirable. The service-learning project allowed the college students the opportunity for authentic practice with these skills with a relatively gentle audience of elementary and middle school students.

Implementing College Service-Learning Pedagogy

As the trends discussed in the next section indicate, valuable learning gains were evident for the college students engaged in the service-learning project. However, it took a couple rounds of iterative revisions to determine how to best meet the revised student learning outcomes. As indicated in Table 3, the entirety of the semester in years 1 and 2 was spent engaging K-8 students via the service-learning project. Although the Mercer students were achieving learning

Table 3. Advanced Biochemistry Laboratory Service-Learning Project

Course student learning outcomes: 1.) Learn to apply the analytical tools used in the modern biochemical laboratory. 2.) Design and implement experiments while working to serve the community. 3.) Learn to use, read, and evaluate the scientific literature and web resources.		
Project Year: ¹	Years 1 and 2	Years 3 and 4
Course enrollment	9 (year 1), 8 (year 2)	9 (year 3), 15 (year 4)
Weeks spent on service-learning	12	4-5
Hours of service per student (approx.)	20	12
Generation of project ideas	College student-generated	Professor-generated
# of partnering schools	3 (year 1), 5 (year 2), plus Museum workshops	2, plus Museum workshops
# of elementary students served (approx.)	180 (year 1), 250 (year 2)	60 (year 3), 92 (year 4)
¹ Years 1-4 are designated for the different semesters in which the service-learning project was implemented. The course had been previously taught by the author without a service-learning component.		

goals 2 and 3, they were not obtaining enough depth and breadth with applying analytical tools of the modern biochemical laboratory (learning outcome 1). For years 3 and 4, the service-learning project became a module, sandwiched between the first few weeks of learning techniques and the final weeks of an independent project. To create more time for the college students to engage with the K-8 students, the project ideas had to evolve from being student-generated (i.e.: students created project proposals for experiments to deliver to the K-8 students) to professor-generated. Although this change necessitated some sacrifice of college student autonomy, the transition allowed for a much better balance of depth and breadth in the college student learning outcomes without affecting the authenticity of the service-learning project.

Growth in College Students' Learning as a Result of Facilitating K-8 Active Learning

As discussed throughout this chapter, content knowledge alone is not enough to ensure students' professional successes (Hart Research Associates, 2010; Vanderford, 2011). However, truly engaging students in their science helps to bridge the gap between college and the professional world (Nair, 2011; Ramaley & Haggett, 2005). Even during the first trial year of the project,

mature and positive feedback was received from the college students enrolled in the service-learning course. The findings from qualitative analysis of this project both corroborate and add to the body of research on student benefits from engagement in service-learning pedagogies (Cone, 2012; Goldberg & Coufal, 2009; McDonnell et al., 2011; Santas, 2009; Sharon, 2012). The detailed insights below were gleaned through careful coding of the qualitative data obtained from the college students enrolled in the biochemistry service-learning course and are representative of the power of service-learning as a pedagogy in science.

Insight 1: The ability to communicate technical information is a crucial life skill. Service-learning provides a context for students to practice and expand their communication abilities.

Representative college student comment: *“To be a successful person, especially someone who’s going into health fields like most of us are, we need to be able to deal with people, whether they’re 80 or 8. I feel like a big part of the project is just learning to deal with people. Depending on the type of science that you go into - actually, pretty much in every field - you’re going to be explaining complicated concepts to people who don’t have the same background as you. This [project] was a baby intro, just getting your feet wet a little bit, because you know that kids are going to eat up whatever you say. They’re not going to question you at all. It was our first chance to try to learn how to communicate in this way. We would be crippled without an experience like this.” (from Year 4)*

As the student points out, learning to communicate technical and scientific information to others is an essential skill and one recognized as such by the American Society for Biochemistry and Molecular Biology (ASBMB). College students in a myriad of courses, not just science courses, are expected to improve their oral communication skills. This takes a variety of formats, from class discussions to group problem solving to formal presentations. Yet, the primary purpose of oral communication is to deliver ideas to another person or group. Too often in collegiate work, one’s audience is the professor or the student’s own classmates. However, this experience of students presenting information to elementary-age children provided an alternate route to the development of those same skills. Since a class of children was depending on them, the

biochemistry students would prepare carefully, but then had to learn to cope with nervousness and think on their feet. They were certainly challenged, but the challenge came in a friendly environment. They knew that the elementary school children were excited to work with them and that they were not judging them or controlling their course grade. Thus, the college students practiced their technical communication skills while being responsive to their audience, achieving success in both areas.

Insight 2: Students were able to apply their knowledge and practice critical thinking and problem-solving skills in unique situations.

Representative college student comment: *“I think that every time that we went somewhere, the entire experience was entirely different than the previous one. Most [traditional] labs here, you go in and normally, all labs are pretty much the same. You have an objective that you had to figure out and you do your work and you get your results and you evaluate your data. Here, we were intrigued and able to act hands-on to do the experiments. It was more hands-on and more visual.” (from Year 2)*

Traditional laboratory experiments certainly have a pedagogical purpose and students learn from them. Yet by including the service-learning module, the course climate was varied such that alternate experiences were encountered. Current research on student learning suggests that learning is enhanced by creating productive environments coupled with intentional opportunities for integration of skills and knowledge (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010). In this project, students were armed with content knowledge, but then never knew exactly what was going to happen when working with the children in the classroom. The challenges present in service-learning assist with transfer of knowledge (Fitch et al., 2013), anchoring student knowledge and experiences with future challenges they may encounter. The college students were perpetually put into the hot seat by their young community partners and had to come up with explanations or alternate procedures on the fly in order to achieve success with their

experiments. This type of active learning was exciting, fun, and productive for the college students and for the elementary school children.

Insight 3: The multiple opportunities for practice with instantaneous feedback created improvements in both interpersonal skills and self-confidence.

Representative college student comment: *“I learned how to execute projects into a presentation format and learned how to organize. It was rewarding to be able to deal with small difficulties and accomplish the scientific tasks after overcoming them. [We would] come back after each experience and talk about what we could have done differently so that the kids could understand better. Although our grades may indicate that we know the material we have been taught the past four years, actually going out and sharing what we have learned proves that we actually have gotten something out of our education.” (from Year 1)*

An oft-cited portion of Bloom’s taxonomy establishes that students performing at the top levels of intellectual behavior accomplish tasks such as assembling, designing, and teaching (Anderson & Krathwohl, 2011). In *Creating Significant Learning Experiences*, L. Dee Fink describes the learner-centered approach to teaching where every course component is carefully designed to scaffold learning and contribute to subject mastery (2003). Students simply cannot reach the higher levels of learning without anchoring their new experiences in what they have already achieved. Likewise, meaningful engagement in the academic sector often produces lasting changes in students’ knowledge base and their understanding of who they are. The students were challenged by this project, but they also learned. Their primary task during the service-learning was this: How do I execute this project and connect with my audience? This is an important problem, but one that the students had the time, energy, and resources to solve. In doing so, they all learned to reach the bar set for them by the course objectives and gained an increased confidence in their scientific abilities.

Insight 4: Learning is stimulated when students encounter and overcome challenges.

Representative college student comment: *“Most of the courses I have participated in during my academic career have focused on what I can learn and what I can generate for assessment purposes. This project forced my classmates and me to develop skills that no other lab has the structure to allow. I learned how to expect the best, but anticipate the worst, taking time to imagine as many ways that a presentation could fail before that had the opportunity to happen. Each group ran into its own set of issues, but by identifying the issues and quickly adjusting them, we were all able to run our reactions more smoothly than the time before. Preparing for damage control and having creative ways to deal with it are essential skills for all realms of life. I learned how to make mistakes under the attentive eyes of the young students and to take responsibility for correcting those mistakes, providing them with accurate and relevant information.” (from Year 3)*

A dearth of challenging activities is detrimental to the development of students’ imaginative skills, which are so essential for the evolving global economy and workforce (Fleer, 2013; Herbert, 2010). An education should provide students the opportunity “to be creative: to learn through doing, to learn through failing, to learn through just having fun” (Selingo, 2011). The college student’s comment above shows how this project required students to be creative and imaginative in their execution of their service-learning project. Although the experiments they were leading at the elementary schools were simple in nature, the college students were still challenged by a myriad of small obstacles that had to be surmounted. They recognized that the challenges contributed to their learning and rather than becoming frustrated by them, worked to develop solutions.

Insight 5: Students took ownership of their projects. Reflection activities throughout the project and as the final capstone gave students an empowering voice in their own education. These are educational attributes often missing in undergraduate science education.

Representative college student comment: *“This is something that freshman year, and even last year, I had difficulty with: when you’re always in the classroom and always looking at books and notes and Power Points, there’s no dynamic or change in how you’re approaching your education or your learning. A lot of times, classes are just the teachers lecturing and you absorb. It gets very heavy and it tires you out and you don’t want to do it. When you change it up and get to do something that is also fun, and you get to learn, that really helps you remember*

it and helps you to enjoy it. The things that I learned to teach little kids are the things that will be permanently engrained into my brain. I really enjoyed this class. When you get to change it up, it helps me as a student get to enjoy that class and want to be there and learn what there is to learn.” (from Year 4)

It is clear that the service-learning pedagogy was empowering for the students. The project was carefully designed to be an important tool to anchor to other student learning outcomes for the college students and not as an add-on. The “change it up” phrase used by this student is representative of what other students also said. The college students did not see service-learning as a detriment to the types of experiments that they would be conducting in a traditional laboratory experience, but rather, saw this project as an alternate route to the same end. As this student indicated, the enjoyment and ownership led to a more deep understanding of the subject matter.

Insight 6: The students used disciplinary-knowledge in the service-learning project. Students were able to broaden their own ideas of the role of a scientist and the role of scientific dissemination to also prepare them for their professional careers.

Representative college student comment: *“The experience that most directly influenced my decision to join Teach for America would have to be the service-learning project I had the opportunity to participate in with my biochemistry II lab...The enthusiasm the kids showed in actively doing the science was very inspiring. This project allowed me to see the sort of impact a fresh approach can have on motivating and engaging young students. It also provided me with a hands-on experience in the education component of science that I was otherwise unfamiliar with...I am confident that I can inspire my students in a similar way to change their perspective on the importance of education and inspire a strong work ethic. I also hope to make college and careers in science a greater reality for those who have been so adversely affected by poverty.”* (from Year 3)

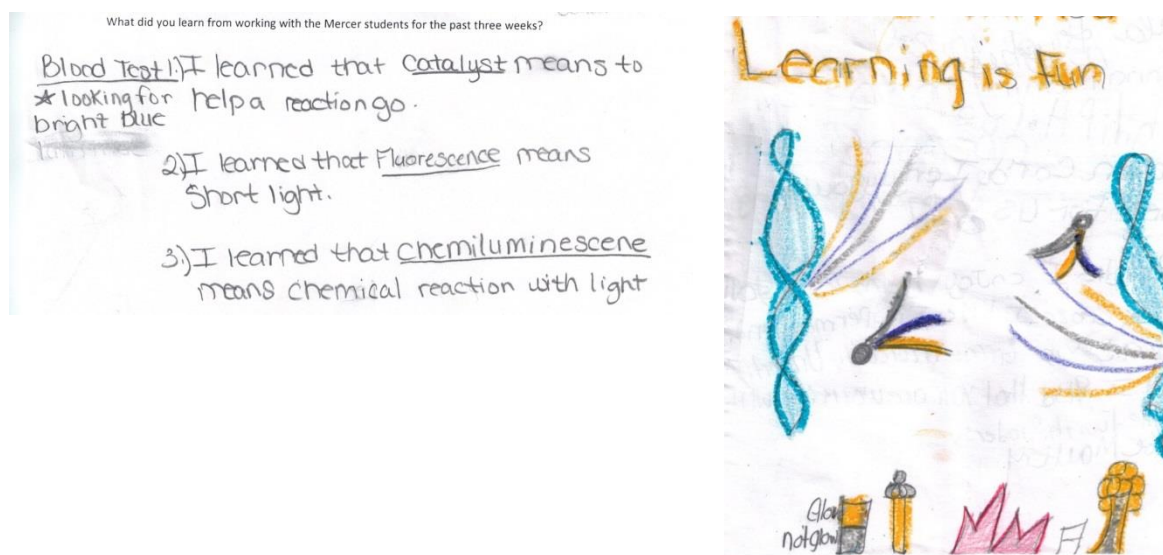
Students in college learn how to be good students, but do not always learn to be good practitioners of science. The quotation above is from a student who took what he learned in the service-learning project and went on to a two-year Teach for America placement before

the experience cemented their disciplinary knowledge with broad skill development. The students were challenged throughout and, as described via qualitative evidence, developed crucial skills that benefit them as they transition into the professional realm. The service-learning opportunity provided much more than anticipated; college students crossed the chasm from being recipients of knowledge to accepting the autonomy for their own learning.

SUMMARY

The focus of this research has been to emphasize insights into educational realities and educational promises that occur as a result of scientific partnerships. Measuring the discrete learning gains of the K-8 students is beyond the scope of this research; nevertheless, the project afforded the elementary and middle school students an opportunity to engage in unique science activities and with a scientific population they would not otherwise encounter. Figure 3 contains two small examples of learning demonstrated by third and fourth graders at a struggling Title I school where 98% of the student population receives free lunch (at or below 130% of the poverty line). In one side of the figure, a fourth grade student proudly articulated her new scientific vocabulary, while on the other, a third grader depicted the concepts pictorially.

Figure 3. Artifacts of elementary student scientific learning



In going to the same schools over a period of a few weeks, we would typically aim to reach all students at a certain grade level. Those students who had already been part of the hands-on activities spread the word to those who had not yet participated so that an audible buzz of excitement followed the college students into the building each week, further moving science from the realm of memorizing obscure facts to an active field ripe for discovery and hands-on learning.

Many of the college students continue to tutor or volunteer to assist with science fair projects on their own time long after they have completed their curricular service-learning requirement. As part of the cultivation of the relationships, the teachers and students at our partner schools and the home-school parents and students at our workshops were able to gain access to equipment and chemicals that they don't usually see. Teachers still invite the Mercer scientists to return to their classrooms year after year, and word-of-mouth from the home-school parents has ensured that the hands-on science events we offer at the Museum are always at full capacity. The community of scientists – students, teachers, parents, and college students – relying upon and supporting each other not only educates scientists in the present, but provides hope and passion for future scientific study.

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