Being a Scientist While Teaching Science
Implementing Undergraduate Research Opportunities for Elementary Educators

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Abstract Aspiring teachers and current teachers can gain insight about the scientific community through hands-on experience. As America's standards for elementary school and middle school become more advanced, future and current teachers must gain hands-on experience in the scientific community. For a teacher to be fully capable of teaching all subjects, they must be comfortable in the content areas, equipped to answer questions, and able to pass on their knowledge. Hands-on research experiences, like the Summer Astronomy Research Experience at California Polytechnic University, pair liberal studies students with a cooperative group of science students and instructors with the goal of doing research that benefits the scientific community and deepens the team members' perception of the scientific community. Teachers are then able to apply the basic research process in their classrooms, inspire students to do real life science, and understand the processes scientists' undergo in their workplace.

Introduction

The content of elementary school and middle school requires a teacher to be able to teach several subjects within the same day, calling for a broad undergraduate education that dips into several content areas for the major. For teachers to feel fully capable of teaching all subjects, they must be comfortable in the content areas. Undergraduates in Elementary Education, or Liberal Studies, learn content associated with STEM education and discover the best teaching practices; however, until recently, there has not been an opportunity for students to perform research alongside a team of scientists.

Being on a diverse cooperative research team with students from various science-related majors allows Liberal Studies students to contribute to the scientific community that they will inspire future students to be a part of as well. At Cal Poly, two liberal studies majors teamed with five physics majors to gain experience as members of an astronomy research team and analyze the experience from an educational point of view.

At first, this opportunity seemed academically beyond the liberal studies majors because the internship focused on key themes studied in many physics classes but not focused on liberal studies classes. Because of this, many liberal studies majors had reservations before pursuing the research experience. Through the experience, the liberal studies majors realized that an interest in astronomy and basic physics skills could carry them through the experience and they did not need to doubt their abilities. The Astronomy Summer Research Seminar at California Polytechnic University proved to be an enriching experience where the liberal studies majors made useful contributions to the scientific community while being on a cooperative team of mixed majors.

Building Confidence

As America increases emphasis on science and math, it is important that teachers are confident teaching the more intensive curriculum. America has remodeled its science standards to adapt to the rapidly expanding technology industry and a society with jobs focused on science, math, and engineering concepts (Conceptual Shifts in the Next Generation Science Standards 2013). With this new, intensive curriculum, teachers must reframe what it means to be an effective teacher (Sheehy 2012). Teachers now have resources and the opportunity for professional development by researching the same concepts that will be taught in the classroom. An online resource for teachers' professional development explains the

paradigm shift in educational philosophy, by saying "Education is no longer defined in terms of what a teacher will teach but rather in terms of what a student will be able to demonstrate. Thus, it is from here that instruction must work backward" (Paradigm Shift in Education). The best way to build a teacher's confidence with math and science concepts is to have hands-on experience and work alongside peers that study these concepts in greater depth. This creates memorable experiences rather than forgettable facts. The Next Generation Science Standards shift from learning the basics of science individually to learning the interconnected nature of science (Conceptual Shifts in the Next Generation Science Standards 2013). This requires teachers to know how to draw connections between different aspects of the sciences. These science standards incorporate engineering concepts into the classroom, and it is therefore invaluable for future teachers to have hands-on experience with these concepts they will be expected to teach. As the head of the Teaching Track Working Group at the University of Ohio, Brian Bardine states in his article "Research to Practice: 'Teacher Research: Getting Started'" (2015) that teachers not only benefit themselves by doing research programs, but they also benefit their colleagues by bringing renovative ideas to the grade level or school site.

Learning the Process and Making Connections

In the Astronomy Summer Research Seminar the undergraduates helped mechanical engineering students with various projects. For example, one of the projects focused on fitting a Gaussian mask on a telescope to better see a binary star system (Loveland, et al. 2015). A mechanical engineer at California Polytechnic University, Ed Foley, created a Gaussian mask as part of his Masters project, for the research seminar team to use for research alongside him. He then showed the researchers how he made it, and explained the steps for using the equipment. Figure 1 shows part of the team posing with the masks that fit on the telescope. Three of the members on the team then obtained certification to use machining equipment, so they could apply these same engineering skills to projects of their own.

The liberal studies majors were a part of a process involving math, physics, astronomy, and engineering concepts, an inspiring example of higher level thinking that can be applied to elementary school and middle school classrooms. The process developed in the seminar could easily transfer over to a K-8 classroom: forming an idea, researching previous models, constructing a model, and using it for future developments.

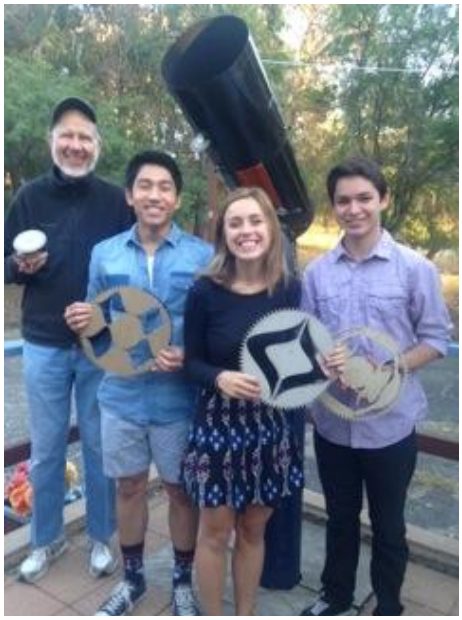

Figure 1: From left to right, Russ Genet, Kevin Phung, Emily Hock, and Donald Loveland show the Gaussian masks developed by Ed Foley.

Advice from a Teacher Scientist

When considering the importance of being a scientist in the teaching profession, it is important to interview current teacher researchers that have ample experience applying their studies to their classes. Author Emily Hock interviewed Dr. David Mitchell, a full-time professor at California Polytechnic University, as well as an astronomer that discovers and researches exoplanets around giant stars, to better understand his dual role as both teacher and astronomer. During the interview, Dr. Mitchell spoke as if he was simultaneously a teacher and astronomer rather than two separate professions. In his teaching profession, he references his research throughout lectures and gives the students real world context, and while doing research, he thinks about how he can improve his classes. David Mitchell received his PhD in Physics, but has always been fascinated by astronomy and has been conducting astronomy research since he was an undergraduate, including documenting and discovering a number of exoplanets. When asked why he thinks liberal studies majors should be a part of a hands-on research experience, Dr. Mitchell made an analogy to his own teaching experience. He said "You have a lot more insight to teaching something when you have done it and gone through the process. It's one thing to understand the basic ideas... I teach Geology 103 [Introduction to Geology], but I am not a geologist, whereas when I teach astronomy, I have done it, so I have a much deeper understanding." This affirms that teachers relate more to their lesson when they have personal experience, portraying to the students that they are passionate and experienced.

Dr. Mitchell also said "It is important to know what a scientist actually does. If your student wants to be a scientist and you are unsure what a scientist does on a day to day basis, [it will be discouraging]. What is an example of what they actually do?" This seems menial, but carries significant weight. It does not make sense to encourage students to be scientists, or anything for that matter, if we do not have a concept of what we are encouraging them to do. Experiencing a research seminar as a teacher gives the instructor a deeper understanding of the career field that they are encouraging their students to be a part of.

In an interview with Natalie LaRosa, current second grade teacher, Cal Poly alumni, and STEM Teacher and Researcher (STAR) program alumni, she emphasized the importance of understanding as a teacher what scientific research actually is. Natalie was a part of the STAR program that gives inservice teachers and future teachers the opportunity to do research with the guidance of a professional researcher. Natalie believes that "You have no merit if you do not understand real world science." This statement suggests that science is not just about memorizing facts, but a process that takes experience to understand. Natalie is preparing to teach second graders in Mountain View, California and says "I will give them [her students] early exposure to real science, and teach them to ask questions." Through asking questions, Natalie's students will have the opportunity to investigate their own questions. She says "If students have a question or curiosity, research gives them a chance to explore and investigate it." Through her experience with research, she will be able to guide her curious students.

An Abundance of Programs

Dr. Mitchell also brought up that there are programs that give in-service teachers opportunities over the summer to do research, so this is not just for undergraduate students. Programs like STEM Teacher and Researcher (STAR), American Association of Immunologists (AAI) Summer Research Program for Teachers, and programs through college campuses across the nation, including Stanford and Columbia Universities, give science research instruction to teachers, enriching their classrooms and keeping them current in science and math concepts. The STAR program helps undergraduates on a teaching path who want to excel in teaching STEM teachers by doing the most real-world science, technology, engineering, and math experience (STAR Program—About STAR 2014). The AAI Summer Research Program for Teachers gives teachers the opportunity to conduct research with Immunologists and familiarize teachers with modern research tools and form relationships with scientific professionals in the community (AAI Summer Research Program for Teachers 2015). The program at Stanford University offers paid research experiences, in addition to class credits (Storm). The unique aspect of the Cal Poly Astronomy Summer Research Experience is that by the end of the summer seminar, the students have the opportunity to publish papers, work through the editing process, as well as enrich their résumés.

Learn by Doing

In comparison to traditional, standard-based curriculum focused on content recall for tests, research shows that the most effective way of learning is by actually creating interactive experiences for students. Educational resources on the internet, such as Astronomical Society of the Pacific online and Cal Berkeley's online lesson database SEGway, have guided lessons for students to follow, with visual aids and interactive components. SEGway has links to follow based on grade level, so the lessons will be appropriate to the science standards of each grade (Complete SEGway Catalog by Grade). The links on the Astronomical Society of the Pacific have lessons organized by topic, making it convenient if a teacher needs a resource to support a specific topic (Fraknoi). These types of lessons typically have aspects of real-world situations, present multilayered problems, guide students to solutions through problem-based activities, and require imagination to do role-playing exercises (Lombardi 2007).

Richard Noss, from the Institute of Education at the University of London, states that the Millenials have "impressive speed understanding technology's potential" which makes in-class use of technology a valuable, and almost necessary addition to interactive lessons (Noss 2012). In application to astronomy, these online tools are very helpful because they are simulators of experiments that would take years to complete, giving students insight into major, big-picture ideas that otherwise would not be accessible. The teacher can take the process they learned through a research experience and online lessons, to build a complete, memorable lesson for their students. When the teacher's experience is paired with learn-by-doing lessons, the students benefit greatly because they are undergoing a smaller-scale version of authentic learning similar to that of the scientific community (Lombardi 2007).

Broad Connections

It is important to acknowledge that without any research experience, the teacher will not have a perfect overall understanding of the research conducted; however, it is likely that with any research, the teacher will be able to relate the seminar to a classroom. Learning the process of having papers edited and published, working with scientists outside of the group, and having to work through glitches—the Summer Astronomy Research Seminar, at the core, has broader concepts that can be linked to any classroom. With this experience, a teacher can now encourage students to work through mistakes, and not fear starting over, because that is what happens constantly in the "real world" (Stremmel 2007).

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