The Benefits of Research in Undergraduate Education: Perspectives From a Teacher and a Student

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Introduction

Inquiry is an important component of science education, and the merits and methods of inquiry are disseminated in the National Science Education Standards (NSES; National Research Council, 1996). Although there are published examples of research experiences at the undergraduate level, it has been reported (MacDonald et al., 2005) that only 1% of a sampling of geoscience faculty in the United States has used research in their curriculum. This is an interesting point given that inquiry is a fundamental practice of scientists in all careers.

The positive impact on student learning via authentic, scientific research and similar experiential activities is documented (e.g., Project Kaleidoscope, 1991; many citations listed in the SERC online portal for Undergraduate Research as a Teaching Practice). In this article we present the perspective of a teacher (Gonzales) and a student (Cammack) on the undergraduate research experience within the context of an igneous and metamorphic petrology class. Our goal is to showcase one example of how undergraduate research can contribute to the academic experiences and career development of faculty and students, and to encourage the use of inquiry as part of the learning process.

A Teacher’s Perspective

As an undergraduate student in 1981 I had the opportunity to work on a research project with one of my instructors. Up to that point in my education a great deal of my academics had involved class activities and exercises with verification of my knowledge and skills via exams. Therefore, I was excited to engage in the process of science on an actual geologic problem. I did not, at this time, however, fully appreciate the significance and potential of this research experience.

In the initial stages of my teaching career I relied mostly on lectures to transfer knowledge, and used exams and class exercises to assess student gains. After several years of instruction a window of opportunity to employ a different format was presented. Igneous and Metamorphic Petrology was a required upper-level undergraduate course that I had taught several times. In 2002, due to changes in the curriculum, this course was eliminated. I was faced with the choice of not teaching a cherished subject or transforming the course into something that would not only allow students to explore topics in petrology, but also give them an opportunity to further develop essential skills as scientists.

In 2003 I created a research-focused petrology course that serves as an upper-division elective for students (Figure 1). The primary pedagogical strategy of this course is to blend field and analytical studies with inquiry to promote authentic, student-driven research. Students use their prior knowledge along with observational and interpretative skills to investigate major regional rock bodies and geologic histories, as opposed to completing a set of class activities with predefined outcomes.

The assessment outcomes of this research course are documented elsewhere (Gonzales and Semken, 2006, 2009) and they illustrate that the students benefited in various ways by designing a research project, collecting and interpreting their own data, and communicating their findings. Students noted that they both enjoyed and were frustrated by the messy process of inquiry involving the testing and retesting of ideas with the potential of not having definitive answers and outcomes. The evidence revealed that this course clearly incited a passion for topics in petrology and geology in students, and gave them a different perspective on their academic experience. Many of the students who took this course have contributed new information to the scientific community through professional presentations. All of the students surveyed in the assessment process noted that they enjoyed research as part of their education and wanted to do more inquiry-based projects.
A Student’s Perspective (Cammack)

I took the research-focused Igneous-Metamorphic Petrology course at Fort Lewis College in 2010 which then evolved into a senior research project on chlorine isotope signatures of rocks in the Navajo volcanic field. The process of conducting original research at the undergraduate level helped make me a more competent geologist and a scientist. The trial-by-fire experience gained through two years of original research helped develop the scientific philosophy and skills that I apply daily in my budding career as a geologist. Learning to do research did not come easily but the process was rewarding in the end.

Doing authentic research (Figure 2) changed my perspectives on scientific inquiry. I realized that it is an ever evolving and complicated process that is not always honestly portrayed in a lecture-centered science class. A linear model for forming ideas, collecting data, and making interpretations is simply not reality. A valuable point that I took away from my experience was that scientific inquiry constantly changes and evolves into new questions and directions. I continually consulted with other students and scientists, and researched others’ work through the entire project. I realized that science is defined by one’s data and analyses, not a collection of facts, and that data always have some degree of error. I came to understand that gathering trustworthy data is a difficult task, with a snake-pit of potential problems. One of the most important lessons I took away from my research experience was that the use of different types of data is important in making valid interpretations.

There were many struggles along my research path. These included: 1) managing my time to deal with the different demands of the project; 2) handling my funding and resources; and 3) overcoming logistical obstacles such as scheduling instrument time to conduct analyses. I learned, with some anguish, that I had to review background information on the subject at all stages of the research. Reading and understanding scholarly articles was necessary to assess previous ideas, and find the relevant inconsistencies or gaps in my research. This was an important step in learning how scientists approach problems, test ideas, and interpret data. This process, however, took a great deal of time and often led to new questions.

The research I conducted as an undergraduate has had a profound impact on my career path as a geologist. Skills that I gained in scientific writing and presentation, data collection, and data management have been applied in several internships and positions. During my first mining internship I was asked to develop and implement a means of using radio-frequency identification (RFID) technology to track ore and waste for an underground mining operation. The project led to implementation of my procedure with recommendations for future steps to complete the project, a presentation to the regional project supervisors, and a job offer. This project required me to: 1) synthesize data and information to design an experiment and test the RFID system capabilities; 2) present the information I gathered to a management team; and 3) use analytical writing skills to generate a summary report. These skills were germinated as a direct result of the original undergraduate research I conducted as a student at Fort Lewis College.

Final Thoughts

From the Teacher

For those teachers who have a passion for a certain topic, but feel briddled by the classroom routine, I encourage you to engage in a research project with students. This activity can open up new ideas and passions in the instructor, and keep us alert to current trends that will help teach the next generations of geoscientists. Doing science in the class allows the instructor to engage with students in a venue where both can further develop professional skills and habits.

There are a number of benefits of having students do scientific inquiry. In the academic setting they can apply knowledge and skills they have learned in classes to assess actual problems. For those of us who promote the Liberal Arts education, research is also a useful tool to help students develop a broader perspective about the role of science in our communities. In the past 20 years, numerous studies have provided evidence that inquiry, especially those involving field activities, can enhance curriculum in modern liberal arts programs and prepare students for diverse workplace challenges (Kirchner, 1994; Schwab, 2001; DiConti, 2004; Plymiate et al., 2005). For the career path, doing research can develop important skills in how to collect and analyze data to solve problems. In essence, students can further develop the critical thinking skills needed as scientists (Gonzales and Semken, 2006, 2009). Multiple conversations with professional geologists reveal that they prefer junior geologists who have the skills and practical experience to address a variety of problems.

Be forewarned, research in the undergraduate classroom is not without its challenges. The logistical issues that are involved in this type of activity can be complicated and difficult to manage (noted in Gonzales and Semken, 2009). One of the main hurdles that I had to overcome was the preconception of many students that there are black-and-white answers to scientific problems. I used to think that students gained an ample understanding of how scientific inquiry worked simply by listening to my lectures, but I have learned the hard way that is not the case. If we do not engage students in actual research they will not understand the complications, pitfalls, and values of this process.

If you have not tried an inquiry-based project in the classroom, the benefits far exceed the challenges. The research experience does not have to develop within the context of an entire course, but can be introduced with class activities, homework exercises, and individual field trips. The good news today is that there is an increasing body of published works and examples of inquiry in the classroom. In addition there are web-based sources of information such as the Undergraduate Research as a Teaching Practice at SERC.

From the Student

I advocate undergraduate research as an irreplaceable component of any scientist’s education and career. As budding geologists, students should know that learning research skills requires a lot of work and getting your "hands
dirty.” In doing research you will develop the skills you need in careers. After my experiences I have developed the opinion that research is not for every undergraduate student. Without ample interest and commitment a student may become frustrated, and gain very little if anything from the involved process of doing original research.

Here are a few recommendations for undergraduate students to consider when taking on an original research project. Pick a topic that excites you, and make sure you develop a project that is reasonable and doable at the undergraduate level. If you are not passionate for the project then don’t become trapped by it. Start your project early, be persistent, and find a professor or other professional who will be dedicated to mentoring your research. I came to realize that a well-designed project is fundamental in the process. You must develop a “thick skin.” There will be times when your ideas are challenged and you have to deal with criticism and setbacks which can be a frustrating. If you select a project that is too broad, and cannot be finished in a reasonable timeframe, it can lead to results that hinder a reasonable assessment of the problem.

For those undergraduate students who are not required to conduct research in their academic experiences, I strongly recommend that you get involved in research project. In my opinion there is no substitute for the pedagogical rewards earned through conducting original research. This activity is an essential component of any science, and lends itself to intrinsic lifelong value. My research experiences as an undergraduate student have motivated me to attend graduate school, and engage in more geologic research. I am enthralled by what is to come in my scientific career, and hope this article will propel other undergraduate students to pursue research as a complement their classroom experiences.

References


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Jake Cammack a recent graduate of Fort Lewis College, and calls Pagosa Springs, Colorado his home. He is an advocate of hands on research experience, and is currently pursing graduate school. He is interested in stable isotope geochemistry, as well as igneous and metamorphic petrology.