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Undergraduate Research Projects Help Promote Diversity in the Geosciences

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Introduction

A workforce that draws from all segments of society and mirrors the ethnic, racial, and gender diversity of the United States population is important. The geosciences (geology, hydrology, geospatial sciences, environmental sciences) continue to lag far behind other science, technology, engineering and mathematical (STEM) disciplines in recruiting and retaining minorities (Valsco and Valsco, 2010). A report published by the National Science Foundation in 2015, "Women, Minorities, and Persons with Disabilities in Science and Engineering" states that from 2002 to 2012, less than 2% of the geoscience degrees were awarded to African-American students. Data also show that as of 2012, approximately 30% of African-American Ph.D. graduates obtained a bachelor's degree from a Historic Black College or University (HBCU), indicating that HBCUs are a great source of diverse students for the geosciences. This paper reviews how an informal partnership between Tennessee State University (a HBCU), the U.S. Geological Survey, and Mammoth Cave National Park engaged students in scientific research and increased the number of students pursuing employment or graduate degrees in the geosciences.

The student projects focused on water resources in a karst terrain and included a wide range of research topics including, parking lot runoff and filter efficiency, groundwater recharge and chemical transport, quantitative tracer studies, karst hydrology model development, geophysical logging, emergency spill response, geochemistry and geomicrobiology (Bradley, et al., 2011; Byl, et al., 2014; Painter et al., 2013; Brown, et al., 2015). These projects used a variety of tools and methods, including field data collection, geographic information systems, chemical and biological analysis, hydrologic instrumentation, modeling and experimentation.

Results of Student Engagement in Karst Research

Tennessee State University (TSU) is a land-grant university offering 45 bachelor's degrees, 24 master's degrees and 7 Ph.D. degrees, located in Nashville, Tennessee, United States. While TSU does not offer a geoscience degree, it has several degrees that introduce concepts about the earth and environmental sciences, such as environmental engineering, agriculture and environmental sciences, biology and chemistry degrees.

Twenty-two students (12 male, 10 female) participated in karst research projects from 2007 to 2015. They represented majors in environmental engineering, mathematical,

chemical and biological sciences. Each student interpreted data collected as part of their research and presented their results at a regional or national conference.

Of the 22 student researchers, three are still undergraduates, two accepted jobs after graduating with a bachelor's degree, 16 went on to masters programs with thesis projects that emphasized earth-science themes, and four students continued into Ph.D. programs (three geoscience majors and one physics major). Of the fourteen students that have completed their academic studies as of May, 2015, ten are currently employed in the geoscience or environmental engineering profession.

When the ten students were asked what influenced them to pursue a career in the geoscience profession, the overwhelming response was their research experiences that allowed them to collaborate with earth and environmental scientists. The student's research experience showed them the importance of water resource studies and environmental studies in helping to solve real-world environmental problems.

The research opportunities and professional meetings also provided an opportunity for the students to learn of employment opportunities, make professional connections, and feel like they could make a difference pursuing a career in geosciences. Another benefit of the student research was the financial assistance, which reduced the need to work off campus.

The benefits of experiential learning through undergraduate research go far beyond developing research methods skills. The outcome for these 22 students support the findings that structured research with faculty or professional geoscientists help students develop cognitive skills, strengthen personal and professional relationships, and improve retention and enhance graduate school aspirations (Haak, et al., 2011; Freeman, et al., 2014). A series of STEM learning models developed by the National Research Council (2005) recognize several key components to successful student learning:

1) Learning and doing are inseparable (Cantwell, 2004). For example, calculating storm runoff from a parking lot or discharge in a cave stream enabled students to "learn science by doing science" (Figure 1).

2) Students learn in deep and enduring ways when they are actively engaged in authentic, real-world project-based problem solving (King et al., 2006). For example, organizing and interpreting large datasets from in situ monitoring equipment provided a lasting impression through real-world applications (Figure 2).

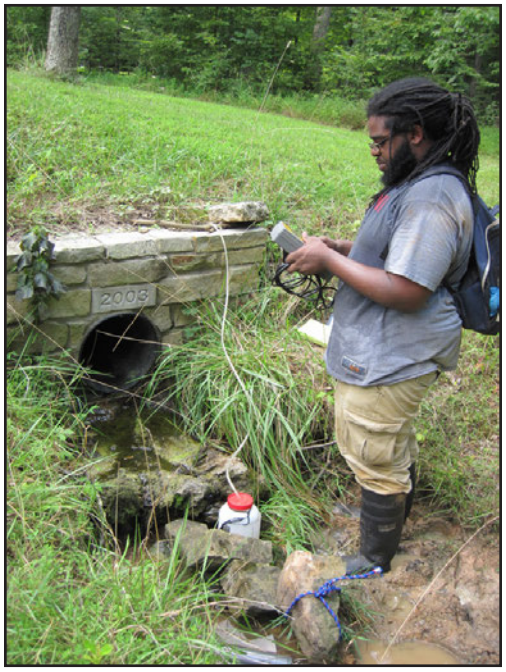

Figure 1: A TSU student setting up a storm monitoring station at the Mammoth Cave National Park Post Office parking lot. (Photo taken by T. Byl, U.S. Geological Survey, 2012)

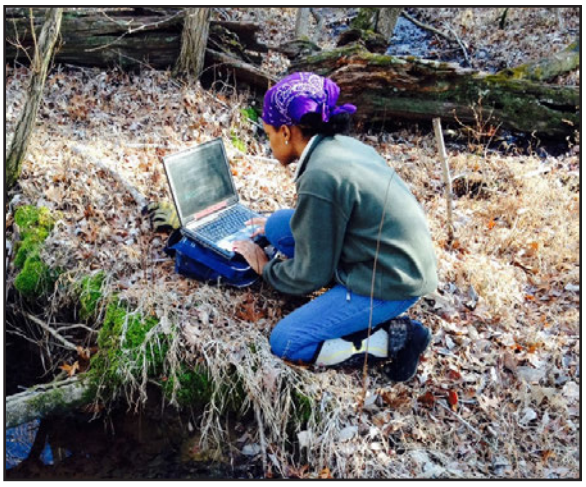

Figure 2: A TSU student downloading data from a monitoring device as part of a tracer study that examined flow from the surface into the caves. (Photo taken by T. Byl, U.S. Geological Survey, 2015)

3) Inquiry-based educational materials (such as problem-based learning modules and case studies) are effective in improving student learning, attitudes, and interests (Michaelson et al., 1996). In this partnership, students applied methods from three previous studies (Mull et al., 1988; Fields, 2002; Palmer, 2007) to conduct quantitative dye studies conducted throughout Mammoth Cave National Park (Figure 3).

4) The students were able to move beyond the class room and experience the scientific method (theory, experimental design, instrumentation, measurement and data collection, data analysis, and presentation) in a real-world setting. This approach is a substantial pedagogical building block that stimulates and retains students, and prepares them well for their professional careers.

Students from TSU were encouraged to consider the issues that were posed by employees from the USGS and Mammoth Cave Learning Center, develop a study plan, work with their mentors to implement the plan, and present the results at an appropriate forum (Figure 4).

Our experiences support findings presented by Villarejo et al. (2008) that undergraduate research experiences also played an important role in student career exploration and career choice. Lopatto (2007) conducted a survey of undergraduate research experiences and found that over 83% of the 1,135 students who participated in undergraduate research programs began or continued to plan for postgraduate education.

Laursen et al. (2010) describe in their book on undergraduate research in the sciences how students perceived their learning to be greater through research than through ordinary classes. Students reported increased technical skill, self-confidence, communication skills, and insight into

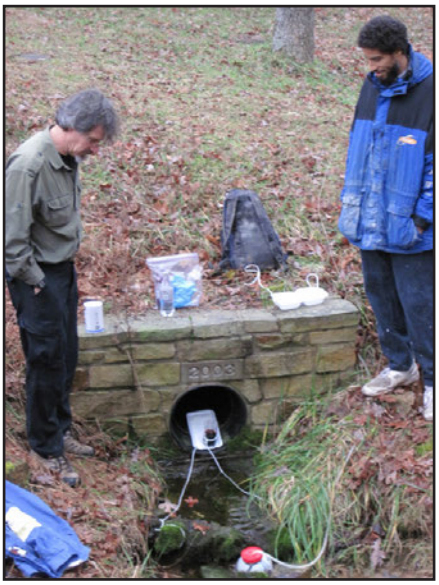

Figure 3: A National Park Service scientist and a TSU student prepare a simple dye-release system for a tracer study. (Photo taken by T. Byl, U.S. Geological Survey, 2011)

advanced study and career possibilities. The improved self-esteem and competence also translated to improved student persistence and retention.

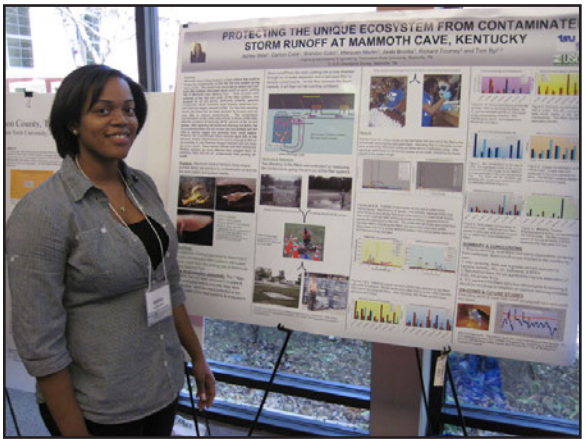

Figure 4: A TSU student presenting her award winning storm-water research at the Tennessee chapter of American Water Resources Research. (Photo taken by T. Byl, U.S. Geological Survey, 2013)

Conclusions

The informal partnership between TSU, the USGS, and the Mammoth Cave National Learning Center is helping to increase diversity in the geosciences through research experiences and professional development. As energy, climate change, water resources, and other earth-science issues become increasingly complex during the 21st century, geoscientists will encounter more difficult problems.

The future success of the geoscience community to help society understand and interact with the Earth system will depend on a diverse geoscience workforce that has insight into topics of concern for race, ethnicity, gender and cultural groups. Institutions must implement programs to increase minority participation in earth science disciplines, increasing the United States' cultural balance and global competitiveness in the coming decades.

In the next 10 years, the jobs available to college graduates will demand STEM skills and knowledge. Recruiting and retaining students with strong academic achievements through real-world geoscience projects becomes the first step in producing college graduates with these necessary skills (Huntoon and Lane, 2007; Murray et al., 2012). A diverse geoscience workforce is essential to helping society understand and respond to increasingly complex geoscience issues, especially with regards to topics of concern for different racial, ethnic and cultural groups.

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