FIELD-BASED RESEARCH EXPERIENCE IN EARTH SCIENCE TEACHER EDUCATION

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ABSTRACT

A pilot of a field-based, research experience in Earth Science teacher education program was conducted for a cohort of secondary science teachers from Prince George's County, Maryland. The goal of this M.Ed. degree program at Loyola College in Maryland was to produce well-prepared, scientifically and technologically literate Earth Science teachers, through a teaching- and research-oriented partnership between in-service teachers and a university scientist-educator. Program participants were exposed to a broad background in field-based instruction in physical, historical, and environmental aspects of Earth Science content and teaching methods, followed by participation in an authentic, technology-rich field research project.

Attrition rates were initially high, as some participants had difficulty with the logistics and conditions of working in field settings. The pilot program was successful, however, in achieving its goal of preparing quality Earth Science teachers through field research experiences. Participants have become confident and innovative in their Earth Science teaching and have developed effective field-based curricula for their own classrooms. The participants have published and presented the results of their societally-relevant geologic study at national and international conferences, contributing to the body of Earth Science knowledge, locally and globally.

Keywords: Education – Field Based; Education – Geoscience; Education – Teacher Education

INTRODUCTION

In September of 1998, the Maryland State Board of Education (MSDE, 1998) declared a statewide critical shortage of qualified, certified, technologically literate secondary-level Earth Science teachers. In the Education Department at Loyola College in Maryland, we already had a variety of teacher preparation programs leading to a Master of Education degree in Curriculum and Instruction, including one with a focus on elementary and middle school science. As a geologist and assistant professor in the department, I was already in the process of designing an equivalent course of study for in-service secondary teachers, when the MSDE put forth its declaration. In response to this critical need, I developed a field-based, research experience-driven, secondary Earth Science teacher education M.Ed. program.

Aimed at bringing cutting-edge research and technology into the public school science curricula, this new program was designed to combine current science teaching practices with first-hand student content experiences. The participants conducted field-based investigations that clearly integrated geologic, geographic, environmental and geophysical techniques, as vehicles for building their own content understanding. The teacher-students could then take that deeper understanding and apply it in their own Earth Science classrooms through innovative curriculum design and teaching methods. The intent of the program was not to duplicate the content of a major or minor in Geology, but to involve classroom teachers in experiences that would allow them to develop a better understanding of what it means to practice Earth Science. The teacher-students were provided access to Earth Science information and, once interpreted, they were better able to teach scientific processes to their own students.

The initial pilot program, partnering myself as a university scientist-educator in research settings with public school teachers, was conducted with a cohort of 17 in-service secondary teachers from Prince George's County, Maryland. A cohort size of 15 to 20 students was the desired goal for a reasonable student-to-teacher ratio, and to allow for the flexibility and mobility required in field studies. Members of the cohort group were required to meet the admissions standards for graduate study at the College, before moving lock-step through the two-year sequence of Earth Science courses designed and conducted specifically for them. As there is no Geology department at Loyola College, I, as a practicing research geologist and experienced K-12 science educator, taught all of the content courses through the Education Department.

The make-up of the cohort group was representative of the population of Prince George's County, and of the teaching population, in general. Most participants were female, with 4 to 10 years of teaching experience. While there was no formal funding used to develop and teach this new M.Ed. program, approximately one-half of each student's tuition was covered by the Prince George's County school system. All program participants were certified, or working toward certification, in a content area other than Earth Science. Most had little or no coursework or formal background in the subject, even though Earth Science constituted a significant part of their teaching load. This situation is representative of the County's public school system, where there are three times the number of teachers teaching Earth Science in the secondary schools than are certified in the discipline (PG Co. school system, pers. comm., 1999).

Certification alone, however, does not ensure quality Earth Science teaching. Following the initial suggestions for science literacy standards addressed in *Science For All Americans* (AAAS, 1989), Project 2061 organized specific grade-appropriate science content goals for achieving literacy in *Benchmarks For Science Literacy* (AAAS, 1993). In each of these works, the Earth Sciences received considerable attention in their importance as unifying themes in the sciences to be studied in the country's schools. This importance is reflected by the inclusion of content standards for the Earth Sciences in the *National Science Education Standards* (NSES) (National Research Council, 1995). Also included in the NSES are specific standards for science teaching, professional development of science teachers and assessment of science education, as well as standards for science education programs and systems.

Many of the changes in science education, as called for in the NSES, concern the manner in which students are taught science. Hands-on, minds-on, inquiry-based learning, in which students are able to personally construct meaning in scientific endeavors and relate them to societal issues are some of the major tenets of the NSES reforms in science teaching. But the NSES go beyond current trends in constructivist, inquiry-based classroom teaching to propose that teacher preparation and professional development programs should be conducted in the same manner, using the same teaching methods as outlined for the elementary and secondary schools. Not only should good science teaching be grounded in current teaching methods and science-related pedagogy, but teachers should enter the classroom with significant experiences in science content, and an understanding of the scientific and technological strategies for the investigation, analysis and presentation of socially relevant problems in science. Intended for pre-service and in-service science teachers alike, the NSES Professional Development Standard A states, in part:

> Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry. Science learning experiences for teachers must:
>
> - Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding.
>
> - Address issues, events, problems, or topics significant in science and of interest to participants.
>
> - Introduce teachers to scientific literature, media, and technological resources that expand their science knowledge and their ability to access further knowledge.

Involving teachers in authentic, relevant investigations requires them to perform like researchers, employing scientific thinking and using available technology to accomplish their task. The ultimate goal for these teachers is for them to translate their understanding of the workings of scientific research into appropriate classroom curricula and learning experiences for their students. Currently, however, teacher-as-researcher trends focus more on science teaching methods and classroom-based assessment strategies, than on science content research brought first-hand into the classroom.

In contrast, Van Zee (1998) reports success using the NSES standards for professional development in teaching both science content and pedagogy by inquiry, involving long-term research projects and student teaching experiences within a science methods course. Still, the component of scientific research in teacher preparation and professional development programs typically suffers from a lack of research-based expertise and/or resources on the part of the institutions offering these programs. Most college and university education departments do not employ practicing scientists in their science education programs, and most science departments do not hire science education and teaching specialists. In most circumstances, research opportunities for teachers arise from collaborations between school districts or university education programs, with university science departments or government research institutions. Typical associations are through internship and summer research institute programs.

The importance of these collaborative efforts is evident in participating teachers' newly found enthusiasm toward inquiry-based science classrooms, inspired by their association with research scientists (Fraser-Abder and Leonhardt, 1996; Crosby, 1997; Bybee, 1998). This enthusiasm translates into innovative science classroom curricula, built upon the teachers' first-hand position of authority on the nature of scientific inquiry, the use of technology and the relevance of science to society (Stockman et al., 1997; Roth and McGinn, 1998). The assertion in these collaborative endeavors is that the quality of science teaching is dramatically improved when a teacher has meaningful, relevant scientific research experience. This assertion extends to the improved quality of technology use in the classroom when a teacher has experience in scientific project design, data collection, interpretation and presentation through current technological media. For these reasons, collaborative associations between classroom science teachers and practicing research scientists have been encouraged and supported by major education organizations such as the National Association of Geoscience Teachers, the National Education Association, the National Earth Science Teachers Association and the National Science Teachers Association. These efforts are also supported by educational outreach programs within various science organizations, including the American Geological Institute, the American Geophysical Union, the Geological Society of America, and the National Science Foundation (NSF, 1997).

The current shortage in qualified, certified, technologically literate secondary-level Earth Science teachers, and the need for pre- and in-service teacher preparation, as well as professional development programs that stress authentic research experiences and inquiry science teaching methodologies, are quite pronounced.

PROGRAM OVERVIEW

In addition to a science-driven, five-course sequence in pedagogical and educational foundations, participants in the field-based, M.Ed. pilot program at Loyola College followed a seven-course sequence in Earth Science content and science curriculum design. Throughout the sequence, students were required to maintain a portfolio of inquiry-based curricula they developed for use in their own classrooms, based on their coursework and field experiences.

Authentic experiences were designed to be a central theme of the Earth Science content sequence, with numerous exercises and field opportunities. The goal was to move the teacher from the role of classroom-based inquiry-learner, to the role of field-based researcher and, finally, to the role of science expert in the classroom. To accomplish this goal, the seven-course sequence consisted of three courses of inquiry-delivered Earth Science content (Physical, Historical, and Environmental Earth Science), before shifting to three courses with a research focus. The first research course was devoted to teaching current methods of Earth Science field research, appropriate for secondary school students. The two other research courses (Global Climate Change and Field

Use of	Interpretion of	Generation of
Hand Transits Surveyor's Transit Systems Hand Augers Vibracoring Apparatus Ground Penetrating Radar	Geologic Maps Soil Distribution Sedimentary Environments Geophysical Profiles	Topographic Maps Land Use/Cover Maps Land Use Potential Maps Topographic Profiles Stratigraphic Cross-Sections

Table 1.Skills and methods stressed for the collection, analysis and interpretation of Earth Science field data.

Study in Earth Science) were concerned with the design, implementation and evaluation of relevant, significant, thematic, field-based research projects. The seventh, and final course in the sequence required the participants to apply their pedagogy coursework and field experiences to the design of collaborative, research-driven curricula for their own secondary classrooms.

In designing the program, I felt that the best way to prepare teachers to effectively use innovative teaching methods to share science content with their own students, was to expose them to the expertise of professional educators and scientists in authentic settings. The result was an interactive learning community, built on a partnership between myself, as a university scientist-educator, and in-service teachers.

The idea of partnership between in-service teachers, education faculty, and practicing Earth Science researchers is directly related to the policy of the Education Department at Loyola College to hire only science education faculty who are both practicing research scientists and K-12 school-experienced science teaching specialists. I view this combination of expertise within a single university department as an asset, in that it allowed for the creation of research experiences that inherently addressed the learning and teaching needs of the teacher participants. Also, the efficiency of planning and executing the pilot program, as well as the ability to advise these teacher-students, was greatly increased by having content and methods unified in one faculty member.

FIELD EXPERIENCE METHODS

At the core of this pilot program was the goal to provide teachers with field-based research experiences in the Earth Sciences, in an effort to improve the quality of their classroom teaching. It was not the aim of this program to turn science teachers into full-time research scientists.

As most of the participants in the pilot program had not been Earth Science undergraduate majors, considerable time was invested in assuring that the teachers correctly and thoroughly learned pertinent methods of Earth Science-related field techniques. These exercises, developed so that they could be included in the secondary classroom, involved methods of collecting and logging field data. The format of these field exercises was designed to allow participants to learn the field skills necessary for future project work in the program, while simultaneously creating curriculum projects for their own classes, based on these acquired skills. These skills are included in Table 1.

The traditional methods of Earth Science fieldwork covered in the program involved the use of hand transits to create thematic maps for future site work. These included topographic, land use and land cover maps. Field relationships of rock structures and rock types were used in the interpretation of geologic maps. Interpretations of soil distribution and recent sedimentary environments were accomplished through lithologic analyses performed on subsurface samples collected through hand-auger borings and continuous cores obtained using a vibracoring apparatus (Figure 1).

Land use and land cover mapping was done in local areas to facilitate the teachers' creation of hydrologic and environmental based projects in the secondary classroom. Geologic map interpretation was carried out in western Maryland, in an effort to support the participants' understanding of long-term, regional scale earth history and tectonic activity. Field analyses of sediment particle size and grain lithology were performed at sites in the Atlantic Coastal Plain in Maryland, to promote an understanding of the use of sediment distribution and surficial processes in paleoenvironmental interpretations.

Knowledgeable Earth Science teaching requires exposure to the more sophisticated technological approaches to Earth Science research in use today. In this program, these approaches ranged from the use of low-end technology in accurate site mapping using a surveyor's transit, to high-end technology in subsurface geophysical surveys employing a ground penetrating radar (GPR) system. These techniques were taught to the students during training exercises, with each tool figuring prominently in the culminating research project near the end of the program.

The use of a surveyor's transit system (Figure 2) in site mapping allowed for the integration of technology with higher-level mathematics in the Earth Science classroom. Basic surveying techniques were used to create accurate topographic profiles for site-based work. Survey and borehole (hand-auger and vibracore) data were combined to compile site maps with subsurface cross-sections. Ground penetrating radar profiling at sites allowed for the generation of subsurface transects used in stratigraphic interpretation and for the optimal location of boring sites (Figure 3). GPR was the geophysical tool of choice for this program based on its relative ease of operation, and its ability to non-invasively produce geologic cross-section-like profiles at shallower depths (accessible to hand-coring devices) than is possible using more complex seismic reflection techniques. The GPR system used in this study was PC-based, menu driven and required only minimal post-collection processing for basic surveys (Figure 4).

Introduction to, and training in, traditional and technological techniques of field-based Earth Science research was the first part of the participants' authentic

Figure 1. Author and teacher-students obtaining a continuous sediment core using a vibracoring apparatus.

Figure 2. Students setting up a surveyor's transit for research site mapping and topographic profiling.

research experience in this program. Students then participated in the design, execution, evaluation and dissemination of an Earth Science field research project of significant importance to science and society. Each student functioned as a member of a team within the overall site-based project. Each team rotated through the collection of geophysical, survey, and lithologic data, ensuring that every student was exposed to each technique during research conditions. Teamwork continued in the post-collection processing, interpretation and reporting of project data. The result was an Earth Science research project that was disseminated to the scientific community through conference presentations, classroom curricula, and a peer-reviewed journal paper (O'Neal et al., 2002a). These presentations and publications occurred on both a national (Pritchett et al., 2001) and international level (O'Neal et al., 2002b), providing the students with a scientific audience and providing a scientific audience with an insight into secondary classrooms. These academic experiences were unknown to the teachers, prior to their entry into the program. Access to such experiences was a valuable learning tool, as the transformation from Earth Science teacher to Earth Science researcher continued. The opportunity for teacher-student interaction with and among practicing Earth Scientists only helped to emphasize the success of this particular partnership of a scientist-educator with in-service teachers.

Figure 3. Program participants retrieve and analyze subsurface sediment samples using a hand auger system.

Figure 4. A geophysics team of teacher/researchers and author perform a common-offset profile using a ground penetrating radar (GPR) system.

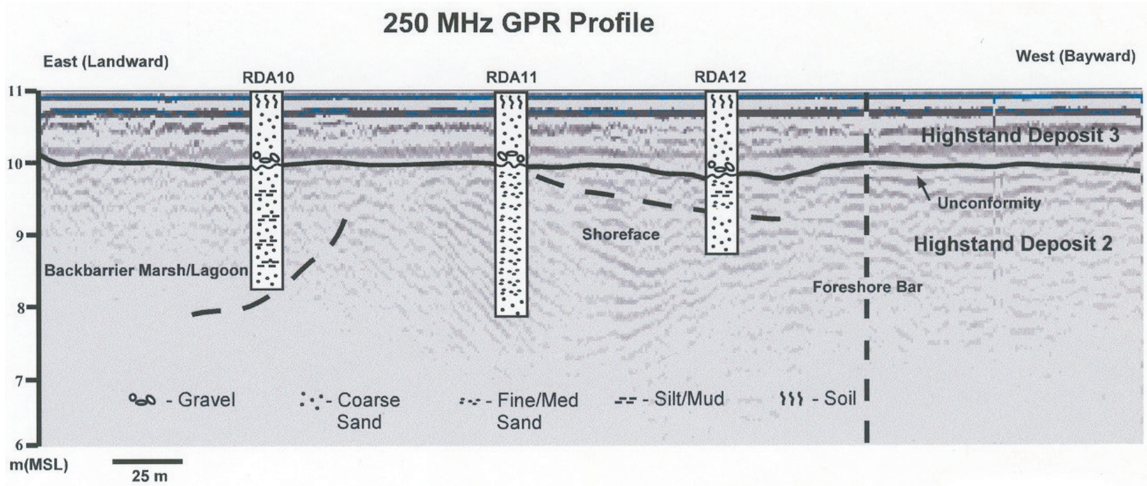

Figure 5. 250 MHz radar profile revealing backbarrier, shoreface and foreshore structures of a stranded, mid-Pleistocene, barrier island-style Chesapeake Bay shoreline, buried in the subsurface on Maryland's Eastern Shore. Students used radar reflections showing sedimentary structures and lithologic analyses from auger borings (RDA 10, 11 and 12) to determine sedimentary environments. Modified from O'Neal et al. (2002a).

FIELD RESEARCH EXPERIENCE

The theme of the field research experience in our pilot program was an investigation of the stratigraphic record of coastal modification in the Mid-Atlantic region, stemming from climate-induced sea level fluctuations during the Quaternary Period. This geologic and geographic framework was chosen for several reasons. As the primary developer and principal content/methods collaborator of the M.Ed. program, I am involved in ongoing, long-term research of coastal climate/sea level records in the local area (O'Neal, et al., 2000; O'Neal and McGeary, 2002). My experience in the Delaware and Chesapeake Bay regions suggested that analyses of the sedimentary record of Pleistocene climate change were within reach, both conceptually and geographically, of local Earth Science teachers. Learning experiences aimed at giving teacher-students the skills necessary for basic sedimentary, stratigraphic, and geophysical studies allowed them to form an effective research team, when we partnered to undertake an authentic field study of sea level change in the Chesapeake Bay area. As an issue in the forefront of public concern on a global scale, the societal relevance of climate change was inherent in this environmental and geologic study. Additionally, the proximity of the research area to the teacher-students' homes and schools added relevance to their classroom curricula.

We convened every other weekend during the summer of 2001, using GPR surveys and lithologic borings to locate and characterize three previously unknown, paleoshoreline deposits on the eastern margin of the Chesapeake Bay, near Cambridge, Maryland. Our analyses revealed these deposits to be barrier island-style features, overtopping one another, having been emplaced during three distinct higher-than-present sea level events during the mid Pleistocene (Figure 5).

RESEARCH DISSEMINATION

The results of this research have been disseminated in four venues. In the first, we gave a research poster at the Annual Meeting of the Geological Society of America in Boston, in 2001, with the teacher-students serving as the primary presenters (Pritchett et al., 2001). Second, the research team produced a peer-reviewed journal article, with the teacher-students serving as coauthors (O'Neal et al., 2002a). In the third venue, I presented the research poster, on behalf of the team, to an international audience at the International Coastal Symposium in Northern Ireland, in 2002 (O'Neal et al., 2002b). The fourth, and possibly most far-ranging venue, was the inclusion of the field research methods and processes learned into collaborative curricula, written by the team for use in their local school district. In these curricula, the teacher-student participants incorporated the classroom, laboratory, and field experiences from this program into their own classroom teaching strategies and content areas.

PROGRAM EVALUATION

The primary intended outcome of this field-based research experience in Earth Science education program was simple: to produce well-prepared Earth Science teachers. The method I chose to achieve this desired outcome was to expose in-service teachers to a broad background in field-based instruction in physical, historical, and environmental aspects of Earth Science, followed by participation in an authentic field research project. The objectives of these methods were to increase teachers' understanding of Earth Science content well beyond their textbooks. Successful participants should be teachers who are well-prepared to be creative and adept at developing and teaching classroom, laboratory, and field exercises, and to bring authority of the subject to their classrooms through a firm understanding of how Earth Science research is performed. A secondary objective of this pilot program was to assess the validity of scientific research conducted by teacher-students in field settings.

To evaluate these objectives, I relied on qualitative data gathered through satisfaction questionnaires, student portfolios, and faculty observations of student growth and performance. As the feasibility of such a field-based program for in-service teachers was at question in general, I opted to focus my efforts on program development and informal evaluation of student experiences.

At both the midpoint and end of the program, each participant was asked to complete an informal satisfaction questionnaire, aimed at assessing their attitude toward the methods and settings in which they had learned content material and teaching strategies, and the applicability of these to their own classroom teaching. Questions were worded generally and were left open-ended for students to elaborate on their responses. Anonymity of respondents was maintained to ensure the freedom to respond openly.

All respondents indicated a high degree of satisfaction with the learning environment created in field settings. Many elaborated that most of the concepts had much greater personal meaning, and were learned in less time than in the classroom, because of the experiential nature of the active, learning environment. This was especially pronounced among those participants who held undergraduate degrees in a discipline other than the Earth Sciences. Most respondents felt that participating in research activities in authentic settings increased the personal relevance of the content when they were required to teach the same subject matter in their own classrooms. Further, these respondents felt that they were able to impart this relevance to their students, based on their own experiences.

Alternatively, some respondents expressed initial difficulty in adapting to unfamiliar learning situations, finding the added complexities of learning outdoors to be a distraction. Those same respondents, however, echoed the positive sentiments of their colleagues once they had undergone an adjustment period of usually no more than a semester. The logistics of fieldwork proved difficult for most program participants, regardless of their response to other questions. All program participants were working teachers, many with families. Most of the difficulties centered on the weekend and summer time required to complete field exercises. Other difficulties arose from personal comfort levels with physical work, temperature and weather extremes, and the lack of amenities in outdoor settings. Participants who chose to withdraw from the program most often cited these difficulties as their rationale for leaving. With an attrition rate of 58% (10 of the original 17), these difficulties inherent in a field-based program must be considered significant. Of the remaining 42% of the cohort (7 of 17), however, it is also significant that all of the teacher-students continued with the graduate program after the initial Earth Science content seven-course sequence, graduating with their M.Ed. degrees.

At both the midpoint and end program assessments, all program participants indicated that they were more confident in their Earth Science content knowledge and teaching ability than they had been initially. All respondents also indicated that they were currently using methods, strategies, and activities they had learned in the program, within their own classrooms.

Throughout the pilot program, a portfolio of student work was maintained for each teacher-student participant. Most notable of the coursework contained in these portfolios were the curriculum projects each student was required to create as the culminating experience in each of the science content courses. Students were given the freedom to develop an activity or project of their own design, which would allow them to bring the course content to their own classrooms. No limitations were placed on the venue for the school-based activity. A clear pattern emerged for each participant of the program, with projects exhibiting an increasing complexity and level of duration, and a decreasing dependence on the school classroom. Initial activities developed were to be conducted in short time periods within the confines of the participants' classroom, whereas subsequent activities were intended to move their students outdoors (both on and off school grounds), placing them in long-term, problem solving situations.

Concurrent with these changes in curriculum development were the faculty observations of personal growth in confidence and independence on the part of each participant. I initially observed most teacher-students approaching their field-study and problem-solving assignments with apprehension, unsure of how to begin a project or pace themselves during a field day. This was most evident in the first field exercise where skills previously taught in the program were needed to make interpretations. By the end of the summer field study session, the participants were routinely observed making independent decisions of where and how to gather data, and freely engaging in field discussions of possible data interpretation. During the poster presentation of their research at the annual Geological Society of America meeting, the attending program participants explained their results to, and fielded questions from, their geologic research peers with confidence and enthusiasm. As the accompanying faculty at the conference, I was not allowed to speak! Such ability on behalf of the students served as further evidence of the successful partnership of a scientist/researcher with teacher/researchers.

CONCLUSIONS

Field-based research experiences in Earth Science education can effectively promote the development of content-qualified, technologically-literate, scientifically-confident, and enthusiastic secondary level Earth Science teachers. The partnering of university scientists/education faculty with in-service teachers provides an opportunity for a coherent learning community where authentic research experiences are designed and conducted with the ultimate goals of the dissemination of research in both professional scientific circles and school-based curricula.

This pilot program has resulted in a published geologic study of societal relevance, contributing to the body of Earth Science knowledge, locally and globally. This research was conducted by a cohort of in-service teachers who have become confident and innovative in their Earth Science teaching, and have developed a network for sharing ideas and teaching strategies. Since graduating with their M.Ed. degrees, two of the seven participants completing the program have taken on administrative roles within their schools, in addition to their teaching positions. Additionally, three cohort members are seeking doctoral programs to further their educational careers, and one has begun teaching at the college level, staying active in Earth Science research.

The Master of Education in Curriculum and Instruction, with a focus on secondary Earth Science, degree program continues at Loyola College in Maryland. In the fall of 2001, a cohort group of teacher-students from another county school system in Maryland entered the program. These students will conduct their field research during the summer of 2003. In addition, the Earth Science M.Ed. program has served as a model for secondary teacher preparation in other science disciplines at Loyola. A cohort of students has recently begun a newly created M.Ed. program for the preparation of secondary Physics teachers, partnering in-service teachers with faculty/researchers from the Physics department.

From the standpoint of a practicing geologist, I feel this program should serve as a model for other scientist-teacher partnerships. The local geologic research program I maintain at Loyola benefited greatly from the teachers' participation, providing more than mere field assistance, but rather a considerably larger data set than otherwise would have been possible to collect in so short a time. Likewise, from an experienced K-12 educator's point of view, I believe this program to be a successful model for Earth Science teacher preparation, where direct, meaningful experiences in field-based research transform Earth Science teachers into Earth Science experts in the classroom.

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