Developing a Paleontology Field Program for Middle-School Students

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ABSTRACT

The University of Montana's Paleo Exploration Project (PEP) was a professional development program for K-12 Montana teachers, which also provided authentic, field-based, residential summer research experiences for over 80 Montana middle school students. The program's scientific focus was the ancient environments and fossils of eastern Montana, which to leveraged student's innate interest in dinosaurs to build a deeper understanding of "doing science" and encouraged future pursuit of STEM coursework and careers. Two week-long summer institutes were held in 2007 and in 2008, with the second year's program being modified based on lessons learned during the first year. In this article, we present qualitative results from students' pre- and post-program surveys and exit interviews, which suggest that the program helped them gain insights into what science is, what scientists do, and how technology is employed in science. Students showed a significant increase in enthusiasm for their upcoming science classes, increased self-efficacy in science and technology, and increased interest in STEM careers. Challenges, insights, and recommendations for implementing residential, field-based science programs for middle-school aged students are presented.

INTRODUCTION

Students' declining interest in science, technology, engineering, and mathematics (STEM) subjects and careers is an international phenomenon with significant implications for society (Lyons, 2006). New approaches are needed to keep students positively engaged in science throughout primary and secondary school and to inspire them to pursue STEM coursework and careers. At a minimum, programs intended to encourage students toward science must be research based, but there are often also logistical and social/psychological challenges that must be identified and addressed through actual practice before programs can be more broadly implemented.

The University of Montana's Paleo Exploration Project (PEP) was an intensive professional development program for K-12 teachers from eastern Montana (authors, 2008, 2009). The project, which involved 52 teachers over two years, focused on the application of geospatial technologies, including global positioning systems (GPS), Google Earth, and geographic information systems (GIS), to scientific inquiry. The scientific theme of the program was the geologic history and rich fossil record of eastern Montana. Teachers received relevant instruction in geosciences and geospatial technologies through a series of two-day weekend workshops, and hands-on research experience during the program's week-long, residential, summer research institutes. These institutes were also attended by middle school students (youths entering the 6^{th} through 9^{th} grades), providing teachers an opportunity to explore technology-embedded, inquiry-based learning with students, and to further their own teaching competencies. The institutes were held in the summers of 2007 and 2008, and involved over 80 middle school students.

A goal of the program was to provide a summer field experience that engaged participating middle-school students in authentic scientific research and discovery, nurtured their interest and self efficacy in science and technology, and inspired them to pursue STEM coursework and careers. Field and laboratory experiences were designed to help students learn how paleontologists and sedimentologists do their work, including how to effectively use standard geological and paleontological research tools such as GPS, surveying equipment, digital cameras, fossil excavation tools, and various computer programs, how to plan and conduct field work, how to collect, record, and analyze data, and how to present results and interpretations.

Participation in the program was open to Montana students entering the 6th through 9th grades. The application required students to write an essay about why they were interested in the program, parental permission, and a letter of recommendation from a teacher. The program was completely free and transportation was provided as needed. No applicants were turned away.

In this article, we describe the impact of this intensive learning experience on students' self efficacy in science and technology, attitudes toward in-school science, and consideration of future STEM careers. In addition, we report on modifications made to the initial 2007 program design in 2008 based on feedback from teachers, students, and program staff, which we believe resulted in a more comfortable and rewarding learning experience.

PRIOR RESEARCH INFORMING THE PROGRAM DESIGN

Critical points along the STEM education and career pathway

Much research has been aimed at identifying the influence of various factors in determining whether students will pursue STEM education and career pathways, as well as when in a child's life these opinions are formed. Studies show that many children develop ideas about careers before leaving primary school (Blatchford, 1992) and that those attitudes can influence later career choices (Hodson & Freeman, 1983; Woodward & Woodward, 1998). In addition, many studies have demonstrated decreasing student enthusiasm for STEM through the primary (Jarvis & Pell, 2002), middle (Morell & Ledermann, 1998), and secondary school years (Simpson & Oliver, 1990; Piburn & Baker, 1993, Gibson & Chase, 2002; George, 2006). George (2006) suggests that this decline may result in part from the type of science courses taken (life science, earth science, physics, and biology), with the greatest loss of science interest associated with the taking of physics classes.

Keeping students engaged in science so that they elect to take more science classes in high school may be a critical step toward STEM careers. An analysis by Holbrook (1997) showed that the probably of a student earning a B.S. degree in a specific scientific field was directly related to the number of high school courses the student had completed in that discipline, a trend that continues today (Van Norden, 2002).

A number of other variables that contribute to students' attitudes toward science and careers have been identified. These include: home background, peer attitudes, career information and images of STEM professionals, academic ability and perception thereof, curriculum content, teacher attitudes, and pedagogy, including the use of extended practical projects or out-of-school programs (Hasan, 1985; Bandura, 1986; Woolnough et al., 1997; Colbeck, Cabrera, & Terenzini, 2000; Jarvis & Pell 2002; Degenhart et al., 2007; Silver & Rushton, 2008). Although various factors are shown to influence different students to differing degrees (Woolnough et al., 1997), student's "self-efficacy" or confidence in their abilities in a particular subject appear to be extremely important (Bandura, 1986; Pajares, 1996; George, 2006; Degenhart et al., 2007). Positive experiences in science have been shown to boost both students' enthusiasm for science as well as their confidence that they could become scientists (Lindner et al., 2007). Certainly, a positive attitude toward science and/or technology is an important precursor to a student's decision to pursue STEM coursework.

Types of science experiences that motivate students

Further research has determined that students find hands-on, self-directed, inquiry-based approaches to science, and involvement in "authentic" science, or that which closely resembles activities that scientists undertake in the real world, more interesting, enjoyable, and motivating than traditional didactic methods (Bencze & Hodson, 1999, Hodson, 1998; Roth, 1997; Woolnough et al., 1997; Woolnough, 1998; Gibson & Chase, 2002). The use of constructionist camps, which focus on student-led projects employing the full cycle of research from development of a scientific question through presentation of results is an area that has received much attention (Papert, 1980), as well as cognitive apprenticeships, in which individual or small groups of students are mentored by professional scientists (Collins, Brown, & Newman, 1989). Use of "affinity spaces" (Gee, 2004), in which participants are brought together through a shared interest in a subject and work and learn together, has proved effective for older students in physical science applications (Fields, 2007).

Out-of-school science experiences, in particular, have been promoted by many researchers as contributing to the learning of science not only by improving the development and integration of concepts through extended and authentic practical work, but also by improving wider dimensions of learning such as attitudes toward school science, and social aspects, including collaborative work and responsibility for learning (Kelso & Brown 2009; Miller et al. 2007; Reiss, 2005; Braund & Reiss, 2006). Rennie & McClafferty (1996) suggest that out-of-school programs should strive to give students a deeper understanding and more positive relationship with science rather than pure cognitive gains. More engaged and positively oriented science students will ultimately perform better in school (Braund & Reiss, 2006) and be better able to maintain a more positive attitude toward science and interest in science careers, even through high school science courses that they find less interesting (Gibson & Chase, 2002).

Among out-of-school experiences, outdoor learning is noted as having excellent potential for positive cognitive, affective, social, and behavioral impacts (Rickinson et al., 2004). Residential fieldwork, in particular, is viewed by some researchers as having great potential to enhance in-school learning of science and other subjects (Amos & Reiss, 2006). Part of this impact may result from benefits associated with collaborative work and social dimensions, mentioned above, which are found to be particularly strong in residential experiences (Bebbington, 2004).

Another much-discussed strategy for improving student motivation and increasing achievement is the employment of technology in learning activities (Park et al., 2009; Cradler, McNabb, Freeman, & Burchett, 2002; Andrews, 2006). There is little doubt that the vast majority of today's students are "digital natives". They show great skill in surfing the web to collect information, using web-based communication tools, video games, and other applications. Studies of the use of PowerPoint in classroom projects reveal that even simple computer applications can give students a measure of autonomy, flexibility, and creative expression that increases their engagement and proficiency, leading them to become more self-sufficient, more willing to share knowledge, and more enthusiastic toward learning (Fedisson & Braidic, 2007).

<u>A logic model for the PEP summer program</u>

The objective of the PEP summer program for middle school students was to provide a residential, field-based, science experience that would (1) be enjoyable and engaging, (2) involve hands-on use of digital technology, (3) provide positive social interaction with peers, and (4) allow interaction with university student and professional scientist role models (Figure 1). Prior research outlined above suggests that these program attributes should help students maintain a positive attitude toward science, increase their self efficacy in science and technology and enthusiasm for in-school science, and help them identify positively with STEM professionals. These outcomes should boost student achievement in science, inspire them to pursue STEM course options in high school, and increase the probability that they will choose STEM careers.

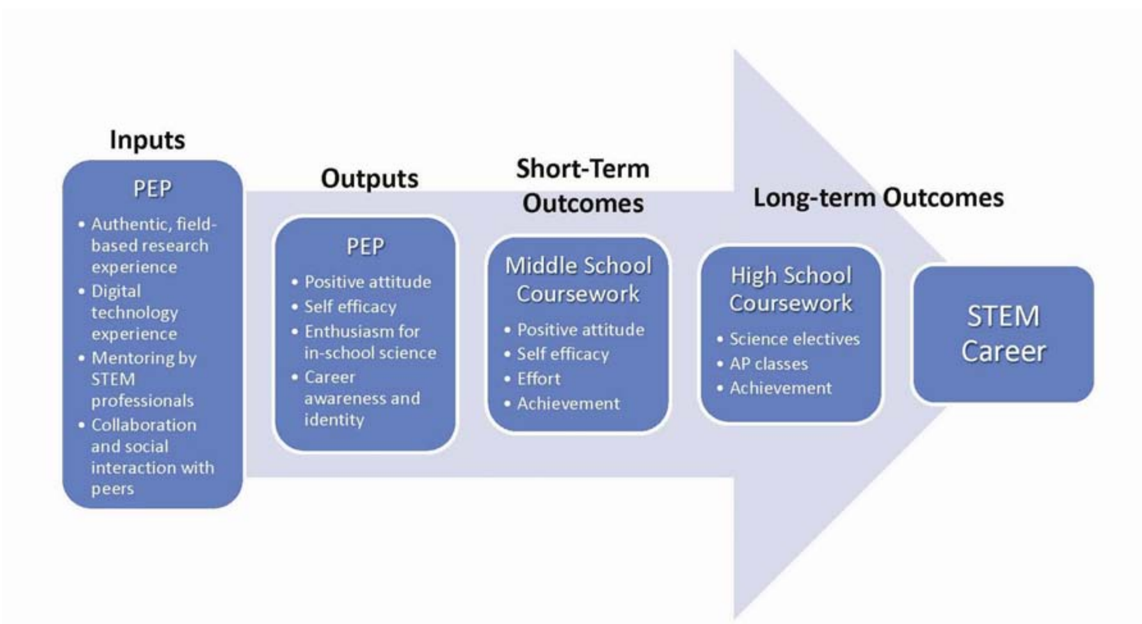

Figure 1: A simple logic model for the PEP summer program for middle school students.

PROGRAM EVALUATION TOOLS

Students were asked to complete pre- and post-program surveys focusing on their attitudes toward school, interest in science and other STEM subjects, interest and comfort level with computer technology, and future educational and career plans. The surveys were designed by PEP project staff with input from project evaluators. The pre-institute survey consisted of 37 items, including three constructed response items and 34 fixed choice items. The post-institute survey consisted of 18 items, including 15 multiple choice items and 3 constructed response items. Multiple choice items were analyzed with descriptive statistics. Constructed responses given by the students were analyzed with simple content count by question. Both pre- and post-institute surveys were completed by 44 of 51 students attending the Year 1 program, and by 34 of 35 students attending the Year 2 program.

Semi-structured interviews in which the interviewer could adapt questions and ask follow-up questions as appropriate were employed. External evaluators interviewed a random sample of eleven students during the summer program in Year 1 and eight students in Year 2 using interview protocols that they had created. Although the order and wording of questions differed between Years 1 and 2, all interviews focused on (1) what science is and what scientists do, (2) the concepts and practices students were taught, (3) their implementation of these practices in the field, and (4) the impact of the PEP summer research experience on students' career plans. Interviews were audio taped and transcribed, and the evaluators took notes during the interviews. The transcribed interviews were analyzed with simple narrative analysis.

Teachers' and project staff's perspectives on the summer institutes were also considered. Informal discussions occurred continually throughout the institutes, so that suggestions or concerns could be addressed as quickly as possible. In Year 2, teachers were asked to complete written reflections on their activities and how students in their group responded to those activities. Finally, senior personnel reviewed the work completed by participants during the institutes with respect to the scientific sophistication of the research questions, data collection protocols, data analysis, and interpretations.

DESCRIPTION OF YEAR 1 PROGRAM

Twenty-five teachers and 51 students participated in the Year 1 PEP summer program. They were divided between two eight-day institutes. Teachers and several senior staff were housed at the historic Fort Peck Hotel in Fort Peck, Montana. Students and junior scientific staff were housed in tents and teepees at a nearby Boy Scout camp, which included a bath house, kitchen, and dining hall. These arrangements were intended to give teachers a break from supervising students each evening, and an opportunity to interact with each other. It was assumed that students would enjoy a more camp-like environment, extended time to interact socially with peers, as well as with undergraduate and graduate scientific research assistants. Evening activities for students included outdoor games, campfire songs, and cleaning fossils.

On the first day, teachers were given a one-day orientation in which the project leaders laid out the learning objectives and schedule for the week and reviewed some of the tools and techniques that would be used in the field. Students arrived on the second day and were also given a brief orientation. Participants were then divided into four research teams of ten to twelve individuals, including three or four teachers with seven or eight students. For the next four days, the entire group travelled by bus to a remote field site on a private ranch about an hour away from Fort Peck. The site consisted of a large and complex arroyo, about 475 m wide and 21 m deep. The site included well stratified sedimentary layers of the Hell Creek formation, which is famous for its abundance of well-preserved dinosaur and attendant plant fossils (Brown, 1907; Hartman, Johnson, & Nichols, 2002; Weimer, 1960).

Program leaders were familiar with the site and knew where specific fossils had previously been discovered. This information was used to develop three field activities, including 1) excavation of a location with abundant fossil plant material, including cycads, ferns and flowering plants, 2) exploration of a bone bed that included some fragmental *Tyrannosaurus* teeth and bones, and 3) measurement of several stratigraphic sections within the arroyo. In addition, partial remains of an almost completely articulated hadrosaurian dinosaur were discovered during the first session and subsequently partially excavated. The teacher-student teams rotated, on a two-hour basis, through the series of field activities. Short breaks were scheduled at each rotation, as well as a 1-hour group lunch break, making each field day, including travel time, over ten hours long.

During the course of the field activities, students learned and practiced appropriate use of several tools and technologies. These included GPS receivers and total stations, which are optical instruments that combine an electronic transit, electronic distance meter, and data collection software for precision surveying (Philpotts, Gray, Carroll, Steinen, & Reid, 1997), as well as digital cameras, hand lenses, field notebooks, and fossil excavation tools.

Each team selected its own research topic related to the field activities. These topics varied widely as they reflected participants' personal interests. Topics included study of the deposition and preservation of the bone bed, identification and interpretation of fossil plants collected, analysis of geomorphologic change within the arroyo, and stratigraphic interpretation and correlation across the arroyo. Students were actively engaged in data collection and discussion, and were required to keep field notebooks on all research activities. Teachers were responsible for leading the students in their group, and guiding them through the research process. University personnel, including geoscience faculty, graduate students, undergraduate students, and professional staff, served as collaborating experts, answering scientific and technical questions and demonstrating techniques as needed.

On the seventh day, teams met at the hotel to analyze their data and develop their presentations. Several groups used Google Earth in their analysis, but although the teachers had been previously trained in GIS, there was insufficient time and inadequate computer facilities to introduce GIS to students. Finally, each team developed a PowerPoint presentation on its research problem, working hypothesis, data collection and analysis, and final conclusions. All of the teachers strove to give students a feeling of ownership of their research projects and allowed them to be creative with their presentation formats and materials. On the final day of the program, a forum was held in which each team presented their work to peers, university staff, and parents. Teachers introduced the students in their group and the students made the presentations.

RESULTS OF THE YEAR 1 PROGRAM

Student Characteristics

Year 1 students included two boys and eight girls entering the 6th grade, eleven boys and 10 girls entering the 7th grade, seven boys and seven girls entering the 8th grade and one boy and five girls entering the 9th grade. The group included nine Native Americans and two Asian Americans.

Thirty percent of the 44 students completing both pre- and post-institute surveys reported that they consider themselves to be "above average" students. The remainder reported that they were "average" students. Seventy-five percent of students reported that they "really like" or "mostly like school", while only two students (5%) said they "mostly dislike" or "really dislike" school. Most students (90%) reported being "very interested" or "somewhat interested" in science and 75 % reported that they plan to attend a 4-year college or university after high school.

Student Experiences

Interest and engagement in science

In the interviews, students were asked about the best and worst parts of their PEP experience. On the question regarding the "worst part of camp," some students echoed what many adults remember from their own camp experiences—rain storms, heat, ticks, and being homesick. However, there were no indications that these negative aspects interfered with students' overall enjoyment and engagement in the experience. All of the students who responded when asked to describe the best part of camp were very positive. They described:

- meeting new kids and making new friends
- learning new skills such as geo-caching and using a GPS
- doing field work and getting to dig for dinosaurs
- playing games, the campfire, etc.

All of the students who were asked said that they would recommend this experience to their friends. The only caveat was one student who stated she would recommend it to friends who were interested in working outside.

However, when asked "How interested are you in science?" on the post-institute surveys (Figure 2), 12 students (28%) reported a lower level of interest than they had in the pre-institute survey, while only six students reported an increase in interest. Most students (58 %) reported no change in interest in science.

Understandings about science

Casual observations of students in the Year 1 program indicated that almost all were very engaged in the scientific research and discovery. They worked hard on their excavations and discovered many fossils of plants, dinosaurs, and other animals. The students learned what they needed to know to conduct the planned field activities and their team research projects, including how to effectively use tools such as GPS receivers, survey equipment, and fossil excavation tools; how to collect, record, and analyze field data; and how to present their findings.

In the interviews, however, students found it difficult to articulate or to generalize what it means to be "doing science," although in later questions they could describe what they did and knew that was doing science. Two students said doing science was fun, four described it in terms of solving a problem or answering a question, five referred to it as learning, and three in terms of the specific activity of finding fossils and dinosaurs. One student stated, "Learning is reading about it, actually doing it is science." When students were asked what scientists do, their answers described developing hypotheses, finding answers to questions, "uncover stuff we don't know," and doing experiments. Only one student could not articulate what scientists do.

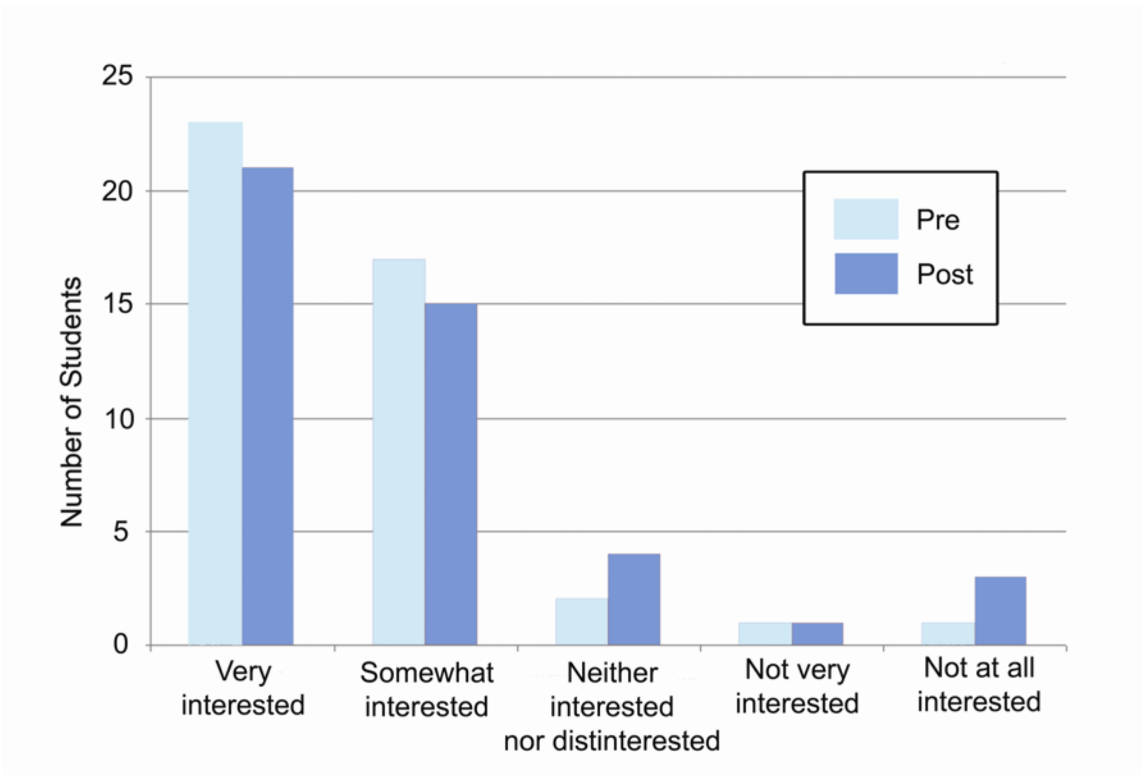

Figure 2: Students' responses to the question, "How interested are you in science?", before and after the summer institutes.

Almost all students could describe how they were prepared and trained to do the field work. Some commented that there was more to the work than just digging. When students were asked to describe how they collected data and interpreted that data, the students provided more detailed answers than to any other question. In almost all cases the students could not only describe what they did in the field, but give reasons why they were doing it and what had been learned. They understood the need to document their work in journals, to write down all data or enter it into the proper equipment (and to make sure it was backed-up), as well as the problems of forgetting to collect data. The students' ability to discuss their analysis of their data was mixed. Some of this was because students had different interpretations of what analyzing data means. For example, one student described that he found a fossil and knew it was a plant, but he did not know what type of plant it was. Other students had similar answers. They knew something about what they found, but there was a lot they did not know and, to some students, this meant that they were not analyzing data. Nevertheless, from a scientific reasoning perspective the students' sense of knowing the complexity of a topic and the extent to which they could answer questions based upon the data and their background knowledge was considered noteworthy.

Expectations for science class

In the post-institute student surveys, students responded positively to the question, "How do you think your science class will be next year?" Seventeen students (39%) stated they thought it would be "more enjoyable" and eleven students (25%) responded "somewhat more enjoyable". Minority students were particularly enthusiastic, with six students (60 %) indicating that their upcoming science class would be more enjoyable compared with thirteen (36 %) White/Caucasian students.

Students also indicated that they felt they would do better in their science class in the upcoming school year. Only 8 students (18 %) indicated their achievement would be "the same" while 17 (39 %) indicated they would do "somewhat better," and 19 (43 %) said they would do "much better." The responses from minority students were also very positive. Only 1 student (10 %) indicated his or her achievement would be "the same" while 2 (20 %) indicated they would do "somewhat better," and 7 (70 percent) said they would do "much better."

Career aspirations

Eight of the eleven students interviewed also envisioned themselves as being a scientist. Many of the students already had interests in careers that were science related and described some of them—medicine, architecture, astronomy, veterinary medicine, chemistry, and computer graphics. On the surveys, the number of students stating interest in a STEM career increased from 23 students (52%) in the pre-program survey to 33 students (75%) in the post-program survey.

<u>Teacher Perspectives</u>

Teachers responded very positively to their experience in the program and to working with students, although they clearly appreciated having their own time each evening. One of the teachers made the following observation about the students, which confirms what the evaluator attending also observed.

"You have some that are very intent on working and finding, and others that it's a little while [sic]. Something that the rest thought was really exciting is boring. That's so typical of this age group. You have some that are so busy, and some that are content to just sit back and let you really work at including them and getting them going. Most of them hung in for the duration, they really did."

With respect to the team research projects, several teachers reported having trouble formulating a viable research question, and a few groups changed their question during the course of the week. Some teachers felt unprepared to fully answer students' questions and felt they needed more time to do background reading around their topics. Several teachers wanted more computer and internet access and more time with the students in the computer laboratory to analyze data and work on their group presentations.

In addition, a few teachers were challenged by the physical nature of the fieldwork. Temperatures were in the mid 90's F in the arroyo, and the terrain was very rugged. A great deal of hiking was required to move from one field activity to another, or to go to the port-a-potty or lunch spot. But while some teachers felt the field days were far too long, others wanted more time in the field. Travelling together by bus to such a remote site made it inconvenient to take participants back to the hotel to rest and recuperate or to allow people to linger longer if they wished.

Staff Perspectives

Overall, the program staff was also very positive about their experience in the Year 1 program, and particularly enjoyed working with students. The interactions with the students even led one of the graduate students to decide that she wanted to teach in the future. However, the research assistants who worked in the field all day and supervised student activities each evening became increasingly exhausted. They also experienced a few disciplinary and homesickness issues with students that they were not adequately prepared to deal with. Although they enjoyed the camping environment, the area experienced heavy rains during the first session, flooding several teepees, and ticks were extremely bothersome.

Program staff also found it difficult to manage so many people in the field and to keep the activities on schedule. They felt that the constant rotations among the various field activities were distracting for participants. A major concern for the project director was the quality of the group research projects. All groups successfully completed and presented a project, but the depth and quality of the work, beginning with the viability of the research questions selected, were limited in some cases. Several groups seemed to have floundered a bit and had difficulty completing their projects in the time available.

ADJUSTMENTS TO THE YEAR 2 PROGRAM

Based on the feedback outlined above, a number of logistical and programmatic adjustments were made to the Year 2 program (Table 1). First, the program was shortened from eight to seven days, primarily to keep the adults from becoming exhausted. Program managers also secured much better equipped student housing at a local church camp, including cabins rather than tents. This provided students with a more comfortable and restful camping experience. A staff of child development graduate students was brought in to supervise student participants after hours, giving the research assistants more rest each day. Strict rules of student conduct were enforced, with each child signing a letter of agreement acknowledging that they would be sent home for bad behavior.

Further, the number of students was reduced to 35, allowing smaller groups and higher teacher to student ratios within groups (1:1.3, rather than 1:2). Instead of staying within one large research site, new field activities were designed that provided a broader suite of activities with each group spending as much time as they wished at each one. Smaller research teams also allowed each group to act autonomously, driving to the research sites in separate vehicles and adjusting their schedules according to each day's activities, weather conditions, or personal issues. Each group was accompanied by different scientific staff each day, depending on the field activity to which they were assigned.

Table 1: Summary of adjustments to the Year 2 summer institute program.

	Year 1	**Year 2**
Length of program	8 days	7 days
Student housing	Tent camping	Cabin camping
After hours student supervision	Junior university scientific staff	Qualified youth development staff
Student conduct	No pre-set guidelines	Strict "no tolerance" policy of bad behavior, pre-program letter of agreement
Number of participants	76 (25 teachers and 51 students)	62 (27 teachers and 35 students)
Working group size	10 to 12 individuals	7 or 8 individuals
Field sites	Various locations within a single site	New site each day
Travel arrangements	All participants travelling together by bus	Each group with university guides travelling independently by SUV
Research projects	Open-ended, developed on site, very little guidance from research staff	Pre-session preparation of teachers with suggested topics and readings, review of proposed research questions by research staff, increased guidance throughout sessions
Computer facilities	Small conference room with one computer per group	Modern lab equipped with one computer per student and large format printer for GIS map production
GIS	Not included	Each group required to produce a GIS map depicting some aspect of their research project
Collection of teachers' reflection data	Informal and interviews of randomly selected teachers	Informal, randomly selected interviews, and structured written reflections

The first activity involved examining a series of outcrops of local geological formations, each of which represents a different paleoenvironment evidenced by diagnostic sediment structures and fossils. Participants were asked to inspect the sediments and fossils they found and determine the environment and age of the formation based on those observations. In another activity participants helped excavate a partial *Triceratops* head shield and attendant plant fossils, including jacketing the skull with plaster and burlap for its subsequent removal from the site. The third activity centered on mapping and interpreting sediment stratigraphy of an exposed bluff (which included an ancient river deposit) using total stations, GPS, and sedimentological data.

As in Year 1, independent research projects were selected and undertaken by each group. However, rather than developing their research questions during the summer institutes, teachers were given a list of potential topics and readings at the prior workshop so that they could select their topic beforehand and gain some background knowledge. Teachers could select a topic from the list provided or one of their own choosing, but their research questions had to be reviewed and approved in advance by project staff. The four projects included determining the developmental stage of the *Triceratops* fossil, identifying and interpreting plant fossils found at the *Triceratops* dig site, studying the distribution of *Triceratops* in North America, and determining whether tiny fossils recovered from ant hills were diagnostic of different geologic formations.

The Year 2 program also placed much greater emphasis on data analysis and computer use, including map creation with ESRI ArcMap. Each group spent two mornings and two afternoons in a computer laboratory, which was equipped with enough computers for each student and ample table space to sort out fossils. In the laboratory, groups analyzed their data, produced large format GIS maps illustrating the spatial extent of the various formations and study sites of interest, and developed PowerPoint presentations. Presentations were conducted on the final day of the program as in Year 1.

RESULTS OF THE YEAR 2 PROGRAM

Student Characteristics

Twenty-seven teachers and 35 middle-school students attended the Year 2 summer institutes. The students included five boys and seven girls entering the sixth grade, two boys and eight girls entering the seventh grade, five boys and two girls entering the eighth grade, and five boys and one girl entering the ninth grade. There were six Native American and two Asian American students.

Thirty-eight percent reported that they were “above average” students, while the rest considered themselves to be “average” students. In this group, 67% of the students reported that they “really like” or “mostly like” school, while only two students (6%) said they “mostly dislike” or “really dislike” school. Eighty percent of participating students reported that they planned to attend a 4-year college or university and were potentially interested in a STEM-related career.

Student Experiences

Interest and engagement in science

Students were very positive about their experience in the program. A typical comment was, "I'm ready to come back next year." Six out of the eight students interviewed mentioned the hands-on experiences as the best part of the institute. Of these six, four specifically mentioned paleontological aspects (digging up dinosaurs/fossils), one mentioned a geological aspect (finding rocks and crystals), and one mentioned technological aspects (computer lab and GPS use). Three students did not have a least favorite aspect of the program, and three students mentioned the weather. (There was a wind storm one day, which curtailed most field activities.) Only two students mentioned content as their least favorite part; one noted the "measuring was kind of hard and confusing," and the other said the computer work was his least favorite part, stating "I'm really a field person."

Several students commented on how exciting it was to do actual field work and that they had not expected to do so. One student said, "I didn't expect to dig up a real dinosaur," while another commented, "I thought they were going to hide them [dinosaur bones] in a sandbox or something." One student noted his surprise that the experience wasn't just about dinosaurs by saying, "I didn't suspect that we'd learn about all the rocks and levels and all that…"

In contrast, however, in the post-institute surveys, students continued to report an overall decrease in their "interest in science". These changes were consistent in both years and with both males and females. Overall, 23 students (29%) reported a decrease in interest in science while 8 students (10%) reported an increase in interest. Of these eight students, two had teacher parents who were participating in the program, and one had made a significant fossil find.

Expectations for science class

As in the Year 1 program, most students reported that their experience in the PEP program had a positive effect on their attitudes toward their upcoming science class. Seventy-two percent felt that their science class would be "more enjoyable" or "somewhat more enjoyable", and 76% felt that they would perform better in science than they had previously.

Understandings about science

In the Year 2 interviews, it was apparent that the students learned about how scientists do their work as well as the nature of scientific research and discovery. Students commented what they learned about how scientists do their work by saying, "Scientists try to figure stuff out, like what the earth was like millions of years ago, what kinds of plants there were, what kinds of animals there were…," and "They are really interested in this, they like to learn about science." Several students commented on the approach the scientists took. Students said, "You have to be patient," and "They [scientists] like to see all of the details; they really like to take their time," while another noted, "You have to look behind the bones and really look. Then you'll see things you didn't see before."

Throughout the interviews, the eight students mentioned aspects of paleontology 64 times, aspects of geology 55 times, and technology 46 times. In talking about paleontology, students talked about “learning how to distinguish bone from rock,” “what the tools were for,” and “there’s lots of different fields—if you want to study plants and animals you can specialize in that.” In talking about geology, students mentioned “how rocks are formed,” how to “measure the grains,” and “measure rock layers.” GPS was referenced 12 times, more than any other technology mentioned, including GIS, total stations, computers, and software.

Although the program’s scientific staff included men and women spanning from approximately 20 to 60 years in age, and included Hispanic, Native American, and Caucasian researchers, students showed no gender, age, or racial bias in identifying who among the adults they worked with were scientists. It appears that being the leader of an activity was the most significant predictor of an adult being mentioned by students as a scientist.

Career aspirations

Six of the eight students interviewed said that since coming to the institute, they have thought about becoming a paleontologist. Three of the students talked about geology as a prospective career, and one specifically mentioned one of the undergraduate assistants and how he climbed up the hills to measure the rock layers. Other prospective careers that students mentioned were archeologist, doctor, anesthesiologist, engineer, marine biologist, museum curator, and architect. Overall, the number of students stating an interest in some type of STEM career remained unchanged at 80% in the post-institute survey.

<u>Teacher Perspectives</u>

Several teachers commented on how much they enjoyed working with the students and that this aspect was notably different from any other professional development experience they had had. In interviews, several teachers said that students from their school were attending the summer institute and that they planned on using these students as “experts” and mentors back in their classroom.

In their written reflections, teachers described how students in their groups engaged in the field activities. The following comment was typical: “The students did a good job of using their field notebooks to sketch and jot down notes in the field. They didn’t hesitate to pull out their notebooks and use them. In fact, we think that they actually enjoyed the role as scientists in the field.”

When asked about their approach to the group projects, one group responded, “Our project was generated with collaborative efforts of both students and teachers. The students’ thoughts and efforts were foremost considered. The students’ knowledge of the programs used to produce the map and PowerPoint was diverse. Therefore, we utilized their abilities and encouraged growth through hands on experience with each program. Adjustments were constantly made to reflect their abilities. We wanted these projects to belong to them and for each student to take pride and ownership of the finished product.”

When asked how well their final presentation reflected what they had learned during the institute, the same group of teachers responded, “Our presentation definitely reflects our knowledge of the programs we used and the research that we did. However, it does not include the personal growth that we gained through staff, teacher and student interactions. These personal interactions were definitely a learning experience also. Our project cannot express the experiences we had out in the field, nor the valuable lessons we learned from the students. The time spent with the students, both in the field and out, was a learning experience that cannot be reflected in a map or PowerPoint."

In a summary comment, another group of teachers wrote, "We feel that this was a great experience for both the students and the teachers. It helped all of us to gain knowledge and experience in this field of science."

Staff Perspectives

The teacher-student research teams were very successful in planning and carrying out their research projects. It appeared that the teacher's increased confidence helped the students conduct their research in a more focused and deliberate fashion. Year 2 teachers made good use of the computer laboratory, where they spent considerable time leading students in discussion, and helping them analyze data. With assistance from teachers and university staff, students were able to create GIS maps of their study sites and embed them in their presentations. Students clearly enjoyed the creative aspects of map-making, including deciding on layouts and colors, selecting photographs, and composing and arranging text. "This is the most fun I've ever had!" one girl exclaimed.

The maps were printed on a 48" color plotter, which delighted the students. Staff hung the maps in the meeting hall for the final presentations. Many students were seen proudly showing their maps to parents who were attending the forum. The students' presentations were likewise very impressive. All students participated, dividing up their content, and supporting each other with the laser pointer. Many students demonstrated a command of scientific vocabulary and concepts well beyond their years.

DISCUSSION

The PEP summer institutes were a learning experience for all involved. Although the Year 1 program was successful in terms of participant outcomes, we believe that the logistical changes employed in Year 2 made for a more comfortable and rewarding learning experience that was better suited to a diverse group of teachers, students, and staff. Everyone was more rested and better able to engage in the work at hand.

The revised schedule and format clearly helped participants become more engaged in the field activities, and all appeared to come away with deeper understandings of paleontology and what it is to "do science". The Year 2 team research projects, as a whole, revolved around better defined research questions, and were more thoughtfully and thoroughly implemented than were those in Year 1.

In addition, having each team spend entire days working on specific activities with a few scientists appeared to increase students' ability to identify with the scientists and to understand how they do their work. As a whole, students in Year 2 were better able than those in Year 1 to describe what science is and what scientists do, appeared to gain a deeper appreciation for the meaning behind various tasks conducted in the field, and identified more closely with scientists as role models. Research shows that those students whose attitudes are influenced by interaction with STEM professionals do so in direct relation to how they compare themselves, either positively or negatively, to that individual (Degenhart, Wingenbach, Dooley, Linder, Mowen, & Johnson, 2007). Apparently, many students related positively to their university mentors. We detected no downside to not having scientific staff involved with students after hours.

Another positive outcome of the program from a mission perspective was the students' increased enthusiasm for in-school science. The fact that 68% of participating students, who for the most part already enjoy science, reported that they expect science class to be even more enjoyable after attending the PEP summer institute validates the notion that these types of experiences can help students maintain interest in science. For 79% to report that they feel they will do better in science next year points to a significant increase in students' self-efficacy toward science. This outcome is particularly important given that in the pre-institute surveys, the percentage of students listing science as a favorite subject declined steadily for each grade level from 33% among 6th grade students to 17% among 9th graders.

A surprising result that warrants further study was the reported overall decrease in students' "interest in science", which is inconsistent with other findings from the surveys, such as improved attitudes toward science class, mentioned above, and the increased interest in STEM careers expressed in surveys and interviews. These discrepancies may be explained by more individual forum for response that interviews provide. Another possible explanation is that the post-program surveys were administered on the final day of each institute, just prior to the final presentations when parents were arriving, and fatigue, homesickness, and stress may have affected the responses of some students.

CONCLUSIONS AND RECOMMENDATIONS

Over the past several decades, a number of strategies have been offered for encouraging students toward STEM career pathways. In this program we have employed several of these, including authentic research experiences, interaction with professional scientists, incorporation of technology, self-directed research, group work, outdoor learning, and a residential setting. Although a significant body of research suggests that interventions should be implemented as early as possible in a child's life, residential programs are simply inappropriate for younger students. In addition, most middle school students are not yet capable of conducting completely self-directed research, and thus a guided-inquiry approach in a small group setting was deemed more appropriate. The program focused more on affective, social, and behavioral aspects of learning, than on specific cognitive gains, as these wider dimensions of learning are thought to have the greatest impact on students' long-term success in science and in pursuing STEM careers.

Comparison of the pre- and post-institute student surveys as well as candid student interviews provide information on how the summer research program affected student interest, engagement, and understandings about science, and how they responded to the experience in terms of their own education and career goals. Specific areas that surfaced included a very positive reaction to the hands-on research activities, including use of technology in the field, improved understanding of the nature of scientific research and discovery and what scientists do, and some increased consideration of science as a career path.

The program appears to have been successful in boosting student self-efficacy in both science and technical skills, but longitudinal studies are needed to determine whether these gains can help sustain student interest in science and technology over time. In addition, many students expressed interest in "coming again next year". Research studies should be aimed at determining what frequency and intensity of various out-of-school learning experiences are most effective in maintaining student enthusiasm for science.

Developing residential, field-based science programs for middle school students is a complex undertaking requiring significant attention to logistical and programmatic details. In rugged and remote settings like the late Cretaceous badlands of eastern Montana, keeping all participants safe and comfortable must be a top priority for a sustainable program. While residential programs allow for extraordinary, immersive experiences, they are also fraught with challenges, including fatigue and homesickness, particularly with younger students. Involving a manageable numbers of participants, and providing adequate housing and experienced, well-rested, around-the-clock staff are key components.

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