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Camp Bioscience: Developing a Biology Summer Camp for Upper Elementary Students

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ABSTRACT: Informal outreach programs can provide authentic science experiences for elementary school students, who may not have these experiences in formal school settings. Research indicates that students lose interest in science in middle school, so it's important to reach them early. To address this need, we designed a summer camp focused on exposing children in 5th grade to current research projects being conducted by STEM faculty and graduate students at the university to increase their understanding of science practices and interest in STEM. This paper describes the outreach model focused on authentic science research projects and direct exposure to scientists and their work. We investigated the influence of participating in the camp on students' understanding of the nature of science, and their interest in science. Data collection included pre-and post-student surveys, observation data, and artifacts. Students reported gains in understanding of authentic science practices on the surveys ($p = 0.0055$), while observation data exhibited a progression of learning throughout the week. Additional data were collected to monitor student engagement with the activities to improve future iterations of the camp as a summer program.

INTRODUCTION

Children in elementary school are natural scientists (Gopnik, 2012), and the popularity of science summer camps suggests that children seek out science experiences. A search on Google for "science summer camp" returns over 400 million results, as of January 2021. While informal science education programs outside of school are well received by elementary school children (Koehler et al., 1999; Feldman and Pirog, 2011), only a few provide authentic science experiences (Fields, 2009; Bhattacharyya et al., 2011). Summer camps focused on biology in conjunction with a university are even more rare (Heise et al., 2020). We created a local biology summer camp that exposed elementary school children to authentic science practices to fill the need for camps that cater to younger students. The camp is built around exposing participants to real-world science by connecting them to current research occurring at a Midwestern University.

Informal education is an important component in fostering student interest in science (Brody 2006; Weinberg et al., 2011). This is an educational experience that differs from formal education, such as traditional compulsory schools because it is primarily participant driven, with voluntary attendees, and can be tailored for all ages (National Research Council, 2009). Unlike formal education, informal education engages learners in education for pleasure, without a focus on testing (National Research Council, 2009). It can be difficult to measure the efficacy of these programs due to the lack of formal assessments, but assessment data in the literature suggests informal programs can strongly influence attitudes, motivation, and engagement in various subjects, especially sciences (Gibson and Chase, 2002; Shanahan et al. 2011; Weinberg et al., 2017).

To address the need for student engagement in authentic science experiences, we developed a science outreach program that would sustain interest in science through interaction with authentic science practices. Summer camp experiences can provide an immersive experience into a specific subject (National Research Council, 2009), allowing participants to interact with the subject matter in a way that is not available during formal schooling. Children, particularly girls, tend to lose interest in the sciences during middle school (Watters and Diezmann, 2003; Sorge, 2007; Agranovich and Assaraf, 2013; Potvin and Hasni, 2014). Intervention through formal and informal education programs can ameliorate this loss of interest (Stake and Mares, 2001; Brody, 2006; Mervis, 2008). Educational interventions are most effective when participants are both learning and practicing science simultaneously (Barab and Hay, 2001). Elementary outreach programs can provide science role models for children at a critical time in their lives and increase interest in science as a possible career (Gibson and Chase, 2002; Shanahan et al., 2011). The University of Akron's Biology Department offers many informal education outreach programs, both on campus and at satellite locations, but has never provided a summer camp experience. We wanted to use University of Akron's existing resources to create a new program to do just that.

When we began to develop our summer camp, we were interested in bringing an authentic science experience to children in an informal learning environment. Authentic science practice incorporates learning about science while practicing science skills (National Research Council, 2012). Previous studies have shown various reasons for waning interest among children and teenagers (Stake and Nickens, 2005; van Eijck and Roth, 2009; Hango, 2013), leading to an incomplete understanding of science practices by students (Gibson and Chase, 2002; Prokop et al., 2007; National Research Council, 2012; Vekli, 2013;).

Increasing understanding of science can lead to increased interest (O'Dwyer and Childs, 2014; Tofel-Grehl et al., 2017). To help sustain interest in the biological science among upper elementary-level children, we decided to focus on bringing authentic science to them through lab modules and lessons that focused on experiences that develop their understanding of science concepts and provide opportunities for developing laboratory skills including data analysis.

SCIENCE CAMPS

Summer camps are informal education programs held during the summer months, when children are on break from school. While summer camps in America were originally developed to encourage good citizenship and experiences with outdoor activities, some included limited education in subjects such as botany and ornithology (Paris, 2008). Many camps now focus solely on specific learning experiences (Barab and Hay, 2000; Paris, 2008; Fields, 2009; Struminger et al., 2018). These learning experiences allow attendees to delve deeply into specific interests and help children retain knowledge through the summer months while not at school (Mittelstaedt et al., 1999; Bell and Carrillo, 2007; Lindner et al., 2014).

Effective summer camps generally share several commonalities in program and structure (American Camp Association, 2006). Many of these common practices were developed to support positive youth development during the camp experience and beyond (Garst et al., 2011). There are many ways to structure a camp, but all of them should include a regular schedule with social interaction between campers, trained staff, and group activities (Garst et al., 2011). Programs should provide a feeling of safety, supportive relationships with counselors, and opportunities to build skills through learning experiences (American Camp Association, 2006).

Best Practices. Several of the best practices for effective summer camps have been previously developed to prevent knowledge loss while out of school and to provide positive experiences for children. Bell and Carrillo (2007) identified the following list of characteristics for effective summer programs:

1. Intentional focus on accelerating learning
2. Firm commitment to youth development
3. Proactive approach to summer learning
4. Strong, empowering leadership
5. Advanced, collaborative planning
6. Extensive opportunities for staff development
7. Strategic partnerships
8. Rigorous approach to evaluation and commitment to program improvement
9. Clear focus on sustainability and cost-effectiveness (p. 46)

These characteristics are meant to guide the approach to both child learning and holistic development while attending a program (Bell and Carrillo, 2007). Science camps have additional, more specific recommendations to promote skill development. Barab and Hay (2000) recommend focusing on participatory science learning in the style of apprenticeship learning. Learning science through immersion into activities and experiments is more effective at developing an understanding of what authentic science practices look like (Mittelstaedt et al., 1999; Barab and Hay, 2000). Additionally, summer camps should be designed with the cognitive capabilities of attendees in mind (Wilson and Chizeck, 2000). The National Research Council has published an extensive framework for science learning (Next Generation Science Standards), which is a useful foundation that can be consulted to align camp programs with age-appropriate concepts and activities found in formal instruction (NGSS Lead States, 2013).

When developing a summer camp learning experience for a new audience, it is essential to follow established best practices for developing informal education programs. The best-practice camp characteristic we focused on during Camp Bioscience was training children in practical, developmentally appropriate, scientific skills (Lindner et al., 2014; Henderson et al., 2007). Additionally, best practices dictate that effective science summer camps should be held in a special location, such as a research field station, and science-related activities should be completed using inquiry-based methods (Bell and Carrillo, 2007). For these reasons, the camp took place at a local field station, which is both a novel location for students and a place with access to spaces suitable for inquiry-based science, given its use as a research site for university scientists.

Camp Locations. Many camps take advantage of outdoor spaces for a variety of learning opportunities (Semken and Freeman, 2007). Experiencing the outdoors through field work can increase positive attitudes in children toward nature (Dillon et al., 2006). Alternatively, inviting children into laboratories to experience science also brings many benefits, including the chance to work with researchers, learn authentic techniques, and participate in ongoing research projects (Hofstein and Lunetta, 2003; Fields, 2009). Facilities such as field stations provide both laboratory and outdoor experiences (Klug et al., 2002).

Field stations are usually extensions of a larger research facility which tend to be located within an area used as a model ecosystem for study (Struminger et al., 2018). These facilities are sites of active research with easy access to undisturbed land and wildlife. Many field stations are centers for outreach to local communities because of proximity to natural phenomena and the excitement of a dynamic, novel environment with scientists performing experiments (Openshaw and Whittle, 2010; Struminger et al., 2018). They also provide natural resource protection while exposing children and adults to positive field experiences (Klug et al., 2002).

Authentic Science Practices. A component of this informal education experience is exposing children to authentic science to create a greater understanding of scientific practices outside school environments (Edelson, 1997; Bredderman, 1983). This exposure to authentic science practices at a young age enables children to continue learning through inquiry in science in all aspects of their lives (Edelson, 1997) Other programs that feature scientists connecting to children have shown positive impacts on attendees (Laursen et al., 2007; Buo and Eagle-Malone, 2021). When students experience science in an authentic setting, they hone critical thinking skills and are better prepared for entry into science-related careers (Weinberg et al., 2011; National Research Council, 2012; Wheeler and Wischusen, 2014; Schwarz et al., 2015).

While developing this summer camp, we focused on several aspects of authentic science practices. These aspects are: 1) working with experts to learn scientific problem-solving techniques, 2) active participation in the camp using acquired knowledge, 3) using authentic tools, and 4) developing science questions to investigate through inquiry-based learning (McGee et al., 2018; Antink-Meyer et al., 2014; Barab and Hay, 2000). We also included elements of good camp design previously mentioned: a regular schedule throughout the week, a safe yet novel environment, counselors to create supportive relationships, and opportunities to build skills (American Camp Association, 2006; Garst et al., 2011).

Benefits to Researchers. Another aspect of creating successful science summer camps is through collaborative design, including university undergraduate students helping design camp activities and scientists creating lab modules. Camp counselors were undergraduate students from the University of Akron and Kent State University. When university students are able to participate in creating and teaching science programs for children, both cohorts of students benefit (Bruce et al., 1997; Koehler et al., 1999). Children are able to interact with scientist role models, which makes science more accessible to youngsters (Koehler et al., 1999; Laursen et al., 2007), while college-age students gain experience in program planning, teaching, and mentoring (Bruce et al., 1997). Experienced members of the scientific community, such as graduate students and established researchers, can also benefit from participating in outreach experiences (Laursen et al. 2012; Johnson et al., 2014). Programs such as “Shadow a Scientist” and “Present your PhD Thesis to a 12-Year-Old” have helped scientists in many ways, including improved communication skills when speaking to non-scientists and gaining new perspectives on current or past research (Clark et al., 2016). Other participants in outreach programs were motivated by a desire to improve teaching skills or even personal enjoyment (Andrews et al., 2004). These studies show that outreach programs can also benefit all science researchers, and undergraduate or graduate students who serve as mentors, by helping them communicate scientific research to the general public, as well as improving their teaching and mentoring skills.

DESCRIPTION OF ACTIVITIES

The summer camp we created, known as, Camp Bioscience, consisted of five days of an immersive science experience for upper elementary school children (entering 5th grade). Camp Bioscience was created around laboratory modules featuring current research at University of Akron and was piloted during the summer of 2018, then implemented with revisions during the summer of 2019. All evaluation was conducted with approval of the Institutional Review Board at the University of Akron.

Camp Setting. University of Akron has a working field station, located on a nature preserve that is open for public use. This field station was established in 1998 and has served since then as both a center of research and education for university students, as well as the local community. The nature preserve encompasses 404 acres of wetland and woodland habitats as well as a lake, stream, and many walking trails. The main building is a former house renovated to contain a classroom space, offices, and an art room, which served as the home of Camp Bioscience for both the pilot program and the full study.

Pilot Program. The Camp Bioscience pilot launched in August 2018. This pilot week was used to test the format of the camp and solicit feedback to improve the lab modules. All participants were recruited from a local charter school, School 1 (S1). S1 is a tuition-free K-8 school for gifted students located in Midwestern city. Children attending S1 have all been identified as gifted using a state-approved assessment. This school attracts children from a large geographic area, including several surrounding counties. Demographics for this school are 58.9% white, 17.5% Asian or Pacific Islander, 10.2% Black, 8.6% multiracial, and 4.8% Hispanic. Almost one quarter (24.7%) of students are considered economically disadvantaged (Ohio School Report Card, c2020). We collected input from participants in order to improve program delivery. Campers were interviewed in groups of three children with one interviewer and were recorded with both camper and parental consent. Interview questions were open-ended and included queries such as “Which lab module did you like the most?” and “What did you learn during the week of camp?” (Figure 1). From the interviews, we determined which modules engaged students in learning and which modules needed to be changed or eliminated from the program (Figure 2).

Using feedback from the pilot program, several changes were made to better align the camp with our goals of creating an authentic science experience for the attendees. We dropped two labs from the first year, Archaeology and Robots. The scientists conducting the archaeological dig during 2018 were finished with their survey, so there was no longer

1. Please describe your camp experience.
2. Which lab module did you like the most?
3. Which lab module did you like the least?
4. Tell me what you thought of the lab modules overall.
5. Did you like the outdoor games and activities?
6. Which outdoor games or activities did you like the most/least?
7. Did you like the indoor games and activities?
8. Which indoor games or activities did you like the most/least?
9. Did you feel like you had enough time to complete the activities?
10. What did you learn during the week of camp?

Figure 1. List of interview questions asked during the final day of the Camp Bioscience pilot program. Children were interviewed in groups of three with responses audio recorded.

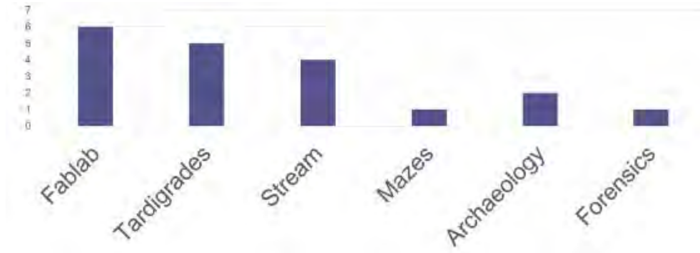

Figure 2. Favorite lab modules from the pilot program as mentioned by campers during interviews. There was a total of 19 responses from 12 campers. Some campers mentioned more than one favorite activity during interviews.

an authentic activity available for camper participation. The Robots lab was discontinued due to low camper interest and many problems with programming equipment available to the camp. We expanded the tardigrade activity from the first year to encompass a full lab module, due to high interest from campers. Along with the tardigrade lab expansion, we decided it would be best to include a module on correct microscope use to ensure attendees understood how to properly handle the scientific equipment.

Other changes included allowing more children to attend, and consequently additional counselors. We also considerably revamped our Biomimicry/Fablab day. Originally, the Biomimicry lab was designed around taking campers to a maker space at a local Community College for the day. This space is called the Fablab and is equipped with computers, 3D printers, laser cutters, and other design tools. The children were asked to think of a nature-inspired design that they could produce with the Fablab equipment. We found that the children spent most of their time playing computer games while waiting for equipment during the Fablab day. This was not in line with our goals of having the children experience authentic biology, so we decided to have the children experience biomimicry modeling through using hands-on materials such as clay and pipe cleaners. The new Biomimicry lab still allowed the campers to create and produce biomimetic products, but without the distraction of computers they demonstrated a better understanding of the concepts.

Participants in Year 2 Program. For the second year of camp, we recruited children who had completed 4th grade from three different schools in the metropolitan area to attend the camp: School 1 (S1, same school as the pilot year), School 2 (S2), and School 3 (S3). We chose these schools because of ease of entry, enthusiasm for assisting in recruiting students, and existing connections. These schools were located in the same state within 35 miles from the camp facility. S2 is an independent coeducational day school for students in Pre-K - 8 located within a National Park. This private school’s demographics show 91% white, 4% Black, 4% Asian or Pacific Islander, and 1% or fewer Hispanic, multiracial, or Native American students (GreatSchools, 1998-2020). While there are flexible tuition opportunities, this school does not cater to economically disadvantaged students. S3 is a private Christian school teaching Pre-K - 12 in a Village. This private school serves families who wish their children to have a foundation in the Christian faith in their education. Demographics show 88% white, 5% Black, 3% multiracial, 3% Asian or Pacific Islander, 2% Hispanic, and >1% Native American students (GreatSchools, 1998-2020). This school also offers tuition discounts as needed.

Twenty students registered to attend Camp Bioscience, however one girl participant never showed up and two other girls decided to not continue with the camp after the first day, leaving seventeen students to attend the entire week. Of the seventeen full attendees, eleven students were boys, and six students were girls. Campers were recruited to the program through either a parent Facebook page (S1) or through the gifted services coordinator employed by each school (S2 and S3). S3 used a blanket recruitment to all children in their program identified as high achieving, while the S2 coordinator invited individual students who expressed high interest in science.

Seven college students from University of Akron and another local University, Kent State University, participated as volunteer counselors for Camp Bioscience. At all times five of the College students were counselors while two recorded observations. Of the seven, three from University of Akron rotated between acting as counselors and recording observations. There was a 1:3.6 ratio of counselors to students for the camp. The counselors had a range of majors from Biology to Education.

Camp Structure. The duration of the fully implemented camp was five days and was conducted from the 13-17th of August 2019. The camp was structured in a way to allow various topics in the field of biology to be discussed throughout the weeklong camp as well as give time for educational games, lunch, and socialization. Each day of the week had an overarching theme tying together the main morning and afternoon activities.

The first section was a lab module which began daily at 9 A.M. and lasted until 11:30 A.M. Each lab was taught by either faculty members or students from University of Akron. Modules began with a presentation, followed by a lab period which challenged participants to complete an activity aligning with the information learned from the presentation. The activities that followed were conducted either in the main room of the field station or at an outside location, depending on the nature of the activity.

From 11:30 A.M. until 12:00 P.M., the students played an outdoor game led by a camp counselor. Each game focused on biological concepts that could be conceptualized in an engaging manner. The games were played in outdoor locations such as fields and wooded areas around the field station. Lunch and free time were from 12:00 P.M. until 12:45 P.M., held in an on-sight pavilion. Counselors were hands-off during this period unless supervision was needed. Students would eat and socialize or play games until the period ended. After lunch, students gathered to perform an activity or game hosted by a counselor or a member of the research team from 12:45 P.M. until 1:30 P.M. These activities focused on concepts that aligned with the content area being covered throughout the rest of the day. The day concluded with another lab module from 1:30 P.M. until 4:00 P.M. The second lab module followed the same structure as the first. Upon conclusion of the second lab module, students were handed a half-sheet of paper that asked them to write what they learned from the day and what questions they still had about the activities. The completed forms were collected at the end of each day and stored by the camp director.

Lab Modules. The Camp Bioscience lab modules were two hours and thirty minutes long, with two modules occurring per camp day. The morning and afternoon modules were designed to tie together for each full camp day. The modules were designed by scientists or students to reflect current work at University of Akron. A description of each lab module follows.

Microscopes. The first day of camp began with a module about microscopes and how to use them, led by a faculty member from University of Akron (here called Microscopes). The lesson began with a talk about the different parts and proper usage of a light microscope and an explanation of the uses of different types of microscopes. Students were then given time to practice with the microscopes. Counselors passed out slides with a typed letter ‘e’ and asked campers to draw their observations as seen from the microscope, as well as a slide with crossed colored threads (Southern Biological, Victoria, Australia) to practice focusing and changing magnification. Counselors assisted students as needed.

After practicing their skills, students were split into groups to collect samples. One group collected samples from the on-site lake and the others collected dirt or mud from a path near the lake (Field Station Permit 2019-006). All samples were collected in small vials and brought back to the field station. Once back in the field station, students set up their slides with their respective samples. For those who collected dirt, mixed it with distilled water before observing. Once their slides were set up, they were once again tasked with focusing their microscopes and writing or drawing their observations. As students finished up their observations, counselors and other camp staff walked around to verify their work and assist with any issues that may have arisen. Upon completion of their microscope work, students had an instructor-led discussion about their findings. They discussed what they observed, any issues they had, and inferences about their discoveries.

Tardigrades. The second lab of the day expanded on the usage of microscopes by observing tardigrades (Tardigrades), led by a University of Akron undergraduate student. The lesson started with a short presentation about tardigrades. Upon completion of the presentation, students were tasked with drawing a radiation-resistant organism and incorporating features which give tardigrades similar abilities. Upon completion of the drawings, students watched a video demonstrating an activity that shows how tardigrades are able to accurately repair their DNA with few errors. After the video, the students were able to participate in a game simulating DNA repair after radiation assault.

Students were taken outside to create 'tardigrade homes' in petri dishes. They collected moss and lichen from surrounding trees and rocks (Field Station Permit 2019-006). Once collected, they returned inside where they were given a dropper full of tardigrades in a solution to place inside the petri dishes. Campers were then asked to find the tardigrades in their petri dishes with the microscopes. If they were unable to find any tardigrades, they were helped by a counselor and given more drops of tardigrade sample liquid as needed. The children were allowed to take the tardigrade habitats in the petri dishes home at the end of the day.

Gecko Adhesion. The second day of camp began with a module exploring gecko adhesion (called Geckos here). A University of Akron graduate student explained animal adhesion to the campers and demonstrated with a live gecko sticking to a piece of clear acrylic. The children were then given synthetic adhesive tabs that mimic gecko adhesion and spring scales. They used the spring scales to measure the adhesive force of the synthetic tabs in Newtons, recorded each experiment and graphed the results. Campers worked in groups and rotated duties of attaching adhesive, pulling the spring scale, watching force readings, and recording results. At the end, all groups shared their data on a whiteboard as a large aggregate graph.

Biomimicry Design. The afternoon module introduced children to the concept of biomimicry, an unfamiliar topic for most (referred to as Biomimicry). The University of Akron graduate student explained that biomimicry is modeling products or inventions on natural systems, such as how the synthetic tabs used in the morning were modeled after gecko adhesive systems. The children were given the option of working together or individually to create a new invention using one of three prompts. Option one was to design a product to prevent people from slipping on ice using polar bear paws, mountain goat hooves, or mussel adhesion for inspiration. Option two was to design a new adhesive bandage based on lotus leaves or tree frog toe pads. The third option was to design a product to regulate body temperature through increasing or decreasing heat loss as modeled by penguin skin and feathers, whale blubber, or elephant ears. The children were provided with a selection of age-appropriate books about the model organisms for research and several types of craft supplies to create prototypes of their products. The day finished with campers sharing their product designs.

Stream. On the third day of camp, we designed two modules to investigate animal intelligence. In the morning, a University of Akron faculty member talked to campers about fish and other aquatic life (here called Stream). He described the types of animals the children would find in a stream on the nature preserve, such as minnows, crayfish, and frogs. We then hiked to a section of the stream that was wide enough for seining nets but shallow enough to walk in. Two or three people held a seine net across the stream while a group of children walked in the water to drive animals toward the net. Any animals collected were placed in a bucket of water for observation before being released. All animal interactions were approved by the University of Akron Institutional Animal Use and Care Committee protocol 17-04-08-BRAC.

Mazes. In the afternoon, during a module here called Mazes, a University of Akron graduate student spent time discussing her research process and explaining that not all researchers use the same scientific methodology. The presentation then moved on to how to test animal intelligence and problem-solving ability, particularly in fish. After the campers made some suggestions, the graduate student explained using mazes to test associative learning. The children were then given materials to create maze prototypes out of cardboard, tape, cardstock, and other paper materials. After giving the children 90 minutes to plan and construct mazes, they were invited to share with the group. At the end, the graduate student revealed pictures of the maze she was currently using for zebrafish associative learning experiments.

Anatomy. The Anatomy Day module was constructed to promote student thinking about the human body and to achieve a basic understanding of the human body and its overall processes (here called Anatomy). To bridge the gap between the idealized image most children have when thinking about a doctor, a second-year medical student from a local Medical School, Northeast Ohio Medical University, was brought in. The anatomy lab took place at four different stations which allowed the students to explore the human body in analogous ways. The medical student ran a station with medical models and answered questions the students had about human anatomy as well as demonstrating how to measure blood pressure. The second station was a "lung demonstration" in which the student used a balloon and a cup to explain the negative pressure relationship the lungs and diaphragm use to allow humans to breathe (Poole et al., 1997). The third station was a yarn organ human body puzzle, in which the students had to place the yarn organs in a body outline. After doing this, the students would choose one of many missing organs and construct their own out of yarn. This helped the students conceptualize the layout of the human body. The last station was one where the students would go outside in a group with a counselor and find an insect. The children would use a provided packet of various insect anatomy models, select their insect, and compare it to the human anatomy models in the first station.

Bones. In the afternoon, the University of Akron Human Anatomy and Physiology lab coordinator visited camp to continue the anatomy lesson and discuss his job at the University (module referred to as Bones). The coordinator brought several artificial bone casts, which were buried by camp counselors in the field station garden. The children were split into groups and taken to the dig site to excavate the bone casts. After the excavation was complete, the children were asked to identify bones and bone structures, sketch bones in their journals, and assemble the skeleton.

Ecology. For the morning lab referred to as Ecology, students were introduced to the relationships between local plants and insects. During a short presentation, a University of Akron graduate student explained a few past and current related studies to the campers to show useful fieldwork that was being done on the subject. The final portion of the lecture included how to do inquiry and methods in the field. Students reviewed the scientific method and how to come up with a good scientific question, then went outside to put it into practice.

While outside, students went on a short nature hike in a field containing prairie grass. Students were asked to make observations and determine a good scientific question about insects in the environment. The campers then broke up into groups of three or four to make observations for approximately five minutes. Once observations were made, students were shown a net sweeping technique to catch any insects that may be found in tall grasses. Students learned how to observe arthropods and were told of some different arthropods that could be found in the field. In pairs, students used 100-meter tape measures to measure out 10 m into the prairie grass field. To do this, each student held one end of the tape measure, one student stood at the edge of the field while the other went into the field until the student on the edge stopped them at 10 m. The student that went into the field then used their net sweeping technique to follow the 10 m that were marked out. After sweeping students determined what type of insects they caught and recorded their observations in notebooks.

Table 1. *Summary of camp week schedule.*

Day	Morning lab module	Afternoon lab module
Monday	Microscopes	Tardigrades
Tuesday	Geckos	Biomimicry
Wednesday	Stream	Mazes
Thursday	Anatomy	Bones
Friday	Ecology	Wrap-up

After students went into the field and completed net sweeping at 10 m, measuring tapes were moved to 20 m out and students were able to try to net sweep in the grass a second time. Campers made collection comparisons to determine if they found different arthropods in the longer section of grass. When finished sweeping for arthropods, students again broke up into their groups to make observations on the scientific question they came up with earlier in the day. Each group took time to decide how they intended to observe and record data for their questions. Data was recorded and students decided to accept or reject the hypothesis they made and shared their scientific question as well as results and methods with the rest of the group.

Wrap Up. There was no afternoon lab module on the final day of camp. Instead, the children were asked to complete the survey as a post-camp comparison with the pre-camp survey. There was a short guest presentation about using mycelium as a building material for a "living wall" structure found on the field station property, followed by science-related games. See Table 1 for the full camp schedule.

PROGRAM EVALUATION

The purpose of Camp Bioscience was to provide upper elementary children authentic experience within a range of biological sciences with the goal of increasing understanding of scientific practices to foster interest in science. The Camp Bioscience program is being treated as a single case study, which allows us to more deeply evaluate the camp for the description of an educational intervention (Kennedy, 1979). The following question guided the evaluation of the program: Was the camp developed in a way to be successful in engaging students in authentic science activities?

Data Collection. To evaluate the success of the program, we used a mixture of qualitative and quantitative assessments to gauge attendee experience at Camp Bioscience. Using these methods helped us determine if Camp Bioscience was meeting its objectives and the efficacy of the overall camp design (Bogue, 2005). The quantitative methods included a modified version of the Student Understanding of Science and Science Inquiry Questionnaire (SUSSI, Liang et al., 2006) used as a pre-post-experience survey and an informal survey. The SUSSI was reduced to two sections, using the parts that were relevant to our goals with the Camp Bioscience program. Children were asked to complete the SUSSI on the first morning of camp, before participating in any activities and again on the final afternoon of camp week (Appendix 1; Liang et al., 2006). The second piece of quantitative data collected was an end-of-camp informal survey on a whiteboard asking children to place a tally mark next to each lab they liked and a check-mark next to a favorite lab.

In addition, we collected qualitative observational data to assess student engagement. To do this, three researchers rotated as observers for each lab module, taking notes on engagement, participation, and evidence of higher-level thinking (Smith et al., 2013; Smith and Scharmann, 1998). The observational data sheet for this program (Appendix 2) was used to collect data relevant to the camp experience. To determine instances of high-level thinking, we used Bloom's Revised Taxonomy, which describes levels of thinking within a hierarchy of increasing skill. For the purposes of this paper, we used evidence of levels three through seven (Applying, Analyzing, Evaluating, Creating) to indicate high-level thinking in camp attendees (Wilson 2016; Limbach and Waugh, 2010).

We also collected exit tickets, which were filled out at the end of each day. These brief surveys asked children to describe what they learned from the day's activities and to list any questions they may have from the day's work (Appendix 3).

Data Analysis. For the SUSSI, the overall and individual question pre-post-camp survey averages were compared by t-test with Bonferroni corrections (Harpe 2015; Derrick and White, 2018). Each camper was assigned a random number to preserve anonymity while allowing pre- and post-test result comparison of each child. Observations and exit tickets were analyzed by coding for instances of higher-level thinking (using Bloom's Taxonomy), and for instances of science learning such as analyzing data, predicting outcomes, and asking conceptual questions. The informal survey was analyzed inductively, and themes were summarized to determine camper enjoyment of each lab module.

RESULTS

Camp Bioscience focused on bringing four aspects of authentic science learning to campers: 1) working with experts to learn problem-solving techniques, 2) using knowledge acquired at camp actively instead of passively listening, 3) using authentic tools, and 4) developing science questions to investigate through inquiry-based learning (McGee et al., 2018; Antink-Meyer et al., 2014; Barab and Hay, 2000). Overall, we found that aspect 3, using authentic tools, was the most widely observed aspect of best practices in creating good summer camp experiences at Camp Bioscience. Of the nine lab modules, six heavily featured the use of authentic scientific equipment. While this is an important characteristic of creating an authentic science experience, it is only one of the four aspects we were interested in. The observational data indicates instances of aspect 4, children using gained knowledge to develop investigative questions, on three of the five camp days, usually when prompted by facilitators or counselors. Children worked with experts every day of camp (aspect 1). Aspect 2 was the most difficult to gauge, but observers noted instances of children using information learned from early in the week about tardigrades and geckos when asked to discuss human anatomy on Day 4.

To what extent did the camp provide authentic science experiences?

Microscopes. The Microscopes lab focused heavily on learning correct equipment use in a scientific setting. Observations for this lab demonstrated little higher-level thinking, with the only instance of authentic science was equipment use by campers. Most exit tickets from this day mentioned the Tardigrades lab, but there were two instances of children mentioning learning how to use lab equipment (microscopes and swabs). There were also six instances of children discussing a mosquito larva found during the sample collection. These children all mentioned how the mosquito looked under the microscope ("Up-close mosquito larve [*sic*] are ugly"). The end-of-camp score for Microscopes was eight likes and zero favorites. Overall this lab module, while necessary to teach proper equipment use, was one of the least successful modules of the camp week, because the only authentic science practice observed was equipment use. However, the foundational aspect of the lab was important enough that it should continue to be included in future iterations.

Tardigrades. The afternoon lab of Day 1 was Tardigrades, which was an extension of the equipment use skills learned in the morning. Our observational data indicated many instances of questions about equipment use with a few conceptual questions in the afternoon during Tardigrades (e.g. "why can [tardigrades] survive in space?"). Observations also indicated that this activity kept children engaged longer than Microscopes, possibly due to the experience of discovering a novel organism. On the exit tickets for the day, two campers asked the same factual question about the tardigrades ("How long do tardigrades live?") and five children mentioned not knowing about tardigrades before the lab. Tardigrades scored 10 likes and three favorites in the end-of-camp survey. This was a more successful lab module than Microscopes, most likely due to the novelty of tardigrades. The children asked many questions during the lab and were beginning to show evidence of scientific thinking (e.g. "How can something be radiation resistant?").

Geckos. Both labs for Day 2 (Geckos and Biomimicry) had an increase in instances of authentic science. Observational data during the Geckos lab describes several instances of higher thinking and evidence of authentic science practices, such as predicting, determining roles within an experiment, and analyzing data. We also observed proper use of scientific equipment and increased peer interaction. Exit tickets continued to show many instances of stating facts related to gecko adhesion ("Geckos have little sticky things on their feet"). The only question on the exit tickets related to the gecko lab was asking to see the live gecko again. End-of-camp score for Geckos was eight likes and five favorites. This was a successful lab, one that encouraged teamwork and analytic skill development. The campers were very engaged during the activity.

Biomimicry. The Biomimicry lab continued to encourage authentic science work among the children. We observed instances of creating, designing, analyzing, and applying research to projects with more instances of peer-peer interactions. Exit tickets demonstrated a few examples of sharing learned concepts ("lotus leaves have little bumps that clean the leaf"). Most of the facts stated were gleaned from the presentation or the independent research conducted by campers while designing biomimetic projects. Biomimicry scored 10 likes and one favorite. This lab module encouraged creativity and teamwork, which are important components of scientific work and understanding. We also saw an increase in conceptual statements this day in observational data and exit tickets ("I learned that Biomimicry is the design of nature"), which demonstrates increases in understanding and higher-level thinking.

Stream. Day 3 started with the Stream module in the morning. Stream exposed children to organisms found in the stream on the nature preserve in preparation for the afternoon's activities. We observed little evidence of higher-level thinking, but the goal of this module was to expose children to the animals in their natural environment. Observers did record instances of proper equipment use with catching and observing wildlife and many factual questions ("what animals are in the stream?", "do crawfish swim backwards?"). Exit tickets for Day 3 contained a few factual statements about this module ("snails are common at camp", "there are more fish in the stream than I expected"), with no questions relating to the Stream module. The end-of-camp score for Stream was 12 likes and three favorites. While this overall lab did not show an increase in conceptual understanding, it was an important introduction to local wildlife before the Mazes lab.

Mazes. The afternoon lab for Day 3 consisted of Mazes, which asked the children to design a learning test for an animal observed in the morning during the Stream lab. Observers during Mazes recorded several instances of authentic science practices, including strategizing and creating maze designs, asking conceptual questions, and forming hypotheses. Exit tickets that mentioned this lab tended to focus on a surprising fact about zebrafish ("zebrafish have really good color vision"), but there were also examples of understanding experiment concepts (using fish in experiments) and a question about the scientific process ("How long does it take to write a paper?"). These questions and facts were related to the presentation given before the maze building activity. Mazes scored 10 likes and seven favorites, the only lab to receive votes from every camper. This day (Stream and Mazes modules combined) had the highest overall end-of-camp score. This lab is considered one of the most successful of the week, with high levels of engagement shown through conceptual questions, creativity, and inferring how an animal would interact with the maze prototypes created by campers.

Anatomy. Day 4 began with Anatomy, a module about human anatomy. This module had few examples of authentic science activity, with some instances of applying information and making connections, such as drawing human-tardigrade hybrids to give human radiation resistance. The activities kept campers engaged but there was little time for creative activities. Exit tickets showed factual statements ("diaphragm goes up but not down", "cartilage isn't a fancy word for bone") and one conceptual question ("Can we make hybrids?") but no other instances of authentic science. End-of-camp scores were four likes and three favorites for Anatomy. This lab showed some campers applying information and making connections, but otherwise there were fewer instances of authentic science understanding and practice in this module.

Bones. During the Bones activity, there was little evidence of authentic science learning. Spacing of dig sites and the need for adequate supervision caused us to split the campers into two groups during this activity. Observers also split up between the two separate groups during the bone dig, and for this reason we cannot use this day's observations as a reflection of the success of the lab module. The one common theme observed between the two groups was equipment use (digging tools). Exit tickets showed factual statements related to this lab ("the skull has 23 bones") but no conceptual learning. Bones received nine likes and two favorites in end-of-camp scores. Even though many children voted for this lab, it should be considered one of the least successful. There were not enough bones in the dig to keep all the children busy the entire lab and splitting the groups did not allow for thorough observations. This module needs significant improvement to be included in the future.

Table 2. *Summary of the informal survey on camper preferences for lab modules*

Lab	Liked	Favorite	Total Votes
Microscopes	8	0	8
Tardigrades	10	3	13
Geckos	8	5	13
Biomimicry	10	1	11
Stream	12	3	15
Mazes	10	7	17
Anatomy	4	3	7
Bones	9	2	11
Ecology	6	1	7
Totals	**77**	**25**	**102**

Ecology. The final lab module on Friday was Ecology, followed by wrap-up activities in the afternoon. We continued to observe procedural and factual questions among campers. There were also examples of authentic science: hypothesis and experiment creation, applying information, and proper equipment use. Even though this lab was not highly scored during the end-of-camp survey (seven likes and one favorite), exit tickets indicated the most authentic science learning happened this day. Several children stated the results of their observational experiments as something they learned ("Pollenators [*sic*] like purple flowers best") along with factual statements. Campers' questions were factual ("What's the biggest katydid?") or about ecological relationships ("Any more kinds of relations?"). We consider this lab as highly successful in increasing camper understanding of authentic science.

Student Engagement with Authentic Science. On the final day of camp, the children were asked to complete a brief informal survey asking them to identify their favorite lab modules. A whiteboard with a list of every lab module was placed at the front of the classroom space of the Field Station and the campers were invited to place a tally mark next to any labs they liked and a check mark next to a lab deemed as the favorite of the week. Several children marked multiple modules as favorites, resulting in more than 17 total check marks. Overall, Mazes was rated highest with 10 likes and seven favorites (17 total). Anatomy and Ecology tied for lowest (seven total each), with Anatomy receiving four likes and three favorites and Ecology receiving six likes and one favorite. This is interesting because even though Ecology was rated as a least favorite lab module, exit tickets from this day show the most authentic science understanding (Table 2).

Table 3. *Summary results for SUSSI questions.*

	Question								
	1A	1B	1C	1D	2A	2B	2C	2D	Avg
Pre	3.88	3.94	4.18	4.18	3.71	2.94	1.94	4.12	3.61
Post	3.71	4.06	4.19	4.53	4.29	4.00	2.76	3.94	3.93
p-value	0.564	0.436	0.414	0.027	0.014	0.0049	0.0042	0.784	0.0055
Significant after Bonferroni correction	No	No	No	No	No	Yes	Yes	No	Yes

Examining the pre-post-camp SUSSI data, we found that there is a significant positive change in the overall score. The average score for the pre-camp survey was 3.61 (on a Likert-type scale from 1-5), post-camp the average was 3.93 (p=0.0055). We also found a significant improvement for two individual questions, 2B (Scientists follow the same step-by-step scientific method; p=0.0049) and 2C (When scientists use the scientific method correctly, their results are true and accurate; p=0.0042). This indicates that campers' understanding of authentic science processes increased, in relation to the scientific method. In this instance, questions 2B, 2C, and the overall average are significantly different between the pre- and post-tests (Table 3).

Results from observation data and exit tickets show a progression of learning throughout the camp week. During the first day of camp (Microscopes and Tardigrades), the questions from students were mainly factual or procedural, such as asking "can [tardigrades] survive in a microwave?" or requesting help with using the lab equipment. On the second and third days (Geckos, Biomimicry, Stream, and Mazes), we noticed an increase in conceptual questioning ("Does [the gecko] choose to be sticky?" "Why do fish like [the color] red?") and other higher-level thinking instances such as applying knowledge, strategizing, predicting outcomes, and designing experiments. On the fourth day (Anatomy and Bones), the children continued to state factual information (stating the number of bones in the human body) and ask conceptual questions ("Can we make hybrids [animals]?") but focused more on identifying structures than applying information. The final day (Ecology) brought a return to applying information and data analysis with the addition of hypothesis and experiment creation. Questions centered around concepts or organisms that had been discussed during lab preparation ("Any more kinds of relationships [between animals and environment]?" "What's the biggest katydid?"). Instances of children demonstrating understanding of concepts increased, particularly within hypothesis forming and experiment creation.

DISCUSSION

When we examine the quantitative and qualitative data as a whole, we see an increase in authentic science understanding over the camp week. Results from the pre/post SUSSI data indicate that over the week the children increased their understanding of key concepts that are often misunderstood, primarily centered around how scientists use multiple science practices instead of one scientific method (Hoisington, 2018; Windschitl et al., 2008). Observational data from the same time period generally increased the instances of authentic science practices along with higher-level thinking, as evidenced by the exit tickets. This indicates that understanding, higher-level thinking, and interest in science go hand-in-hand. All of these components must be considered when creating a successful informal science experience for upper elementary students.

Overall, Camp Bioscience attendees indicated that they enjoyed attending camp and a majority of the lab modules. As seen in Table 2, we found increases in understanding of authentic science practices in relation to how scientists use the scientific methods after the week of camp. Because we did not focus on how scientists use observations and inferences and how those can differ between scientists, we did not see growth in this area, which is corroborated by the qualitative data. Observational data showed that by the end of the week, children were more focused on answering scientific questions, also demonstrated by exit ticket results.

Previous work has shown that students with exposure to science through informal programs tend to increase interest, understanding, and positive attitudes toward science (Tofel-Grehl et al., 2017; Clark et al., 2016; O'Dwyer and Childs, 2014), especially in girls and young women (Tyler-Wood et al., 2012; Packard, 2003). Science-based out-of-school experiences encourage interest among students, particularly when the experiences include exposure to authentic scientific work and scientists (Braun and Reiss, 2007). Camp participation showed similar improvements in understanding as evidenced by changes in scores on the SUSSI survey and observation data indicating high interest.

Implications. For future iterations of Camp Bioscience, we have several recommendations for improvement. Most importantly, we would recruit attendees from a more diverse population to include more campers from minoritized groups. Studies have shown that positive experiences in the sciences can greatly benefit students from minoritized groups (Hurtado et al., 2008), who are underrepresented in STEM careers. For this study we used a convenience sample of volunteers from specific schools that we had existing relationships with, but future iterations of the program will focus on recruiting students of color from the community at large.

Counselors should have more training in how to interact with the campers prior to the start of camp. Some counselors acted in a more directive manner than others, possibly resulting in an unequal experience across groups of children. One of the criteria that was listed on the observation protocol was interactions with peers, and we found that most of the children directed questions to the counselor assigned to their group instead of discussing with peers. Future counselors should attempt strategies to facilitate peer-to-peer interactions. Additionally, observers should also have more training prior to conducting observations.

Regarding camp modules, we would move the microscope instruction day to the second day of camp. We feel that focusing on equipment use in the very beginning may have not been engaging, which may have caused two children to leave camp after the first day. Starting with introducing a phenomenon may have been a more exciting start to camp, such as with the Gecko or Stream labs. We would also add more critical thinking to the Bones lab with additional activities because the dig activity finished too quickly with so many children.

CONCLUSION

Camp Bioscience was a new summer camp program created for students entering 5th grade. This program was able to provide a week-long immersive science experience covering a range of biology topics currently being studied at a university. University of Akron's biology department has never offered a day camp before at its field station, even though it had the capacity and resources to do so. We created a camp that engaged children and increased their understanding of an important aspect of authentic science —the use of science investigations. We also saw an increase in children using scientific practices such as analyzing data, predicting outcomes, and forming hypotheses. These increases in understanding may help increase interest in the sciences as seen in previous studies (O'Dwyer and Childs, 2014; Tofel-Grehl et al., 2017). In this respect, we consider Camp Bioscience a success.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this the manuscript.

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ABBREVIATIONS

NGGS: Next Generation Science Standards; SUSSI: Student Understanding of Science and Science Inquiry Questionnaire

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