Conceptual Understanding of Geological Concepts by Students With Visual Impairements

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ABSTRACT

Eighteen middle and high school students with visual impairments participated in a weeklong field-based geology summer camp. This paper reports the curriculum, strategies, and what the students learned about Earth science by climbing in and out of caves, collecting fossils, exploring a bog, and interacting with experts in the field. Students were encouraged to be active learners outside of their normal comfort zone to develop understandings about geology through reading the landscape. Initially, few of the students held scientifically accurate Earth science concepts, but by the end of the week most had developed a medley of scientific and unique inaccurate understandings that have never been documented before. A week of intensive first-hand experiences was sufficient for the students to acquire some scientific knowledge, but not enough to eliminate inaccurate understandings. The duality of their science understandings suggests that additional informal experiences paired with formal classroom instruction will be necessary to clarify concepts. Some previously undocumented misconceptions were exhibited by the students, such as water pressure influencing plate tectonics and lifecycles of animals impacting Earth systems. © *2013 National Association of Geoscience Teachers*. [DOI: 10.5408/12-379.1]

Key words: geosciences education, informal science education, visual impairment

INTRODUCTION

Historically, the study of Earth systems has received short shrift in K–12 education (Lewis and Baker, 2010). Recent public debate regarding the need for alternative energy sources and the merits and alleged deleterious effects of fracking indicate a particular need for students to understand Earth science to become informed citizens. To meet the needs of 21st century learners, Earth science studies need to be taught from a systems view that employs inquiry-based lessons supported with geological reasoning (Hoffman and Barstow, 2007).

SCIENCE EDUCATION FOR STUDENTS WITH VISUAL IMPAIRMENTS

Approximately 29,000 students aged 3–21 have a visual impairment in the U.S. (U.S. Department of Education, 2011). Students with visual impairments have considered science a difficult subject, due to the overreliance on visual instruction techniques (Penrod et al., 2005; Jones et al., 2006; Sahin and Yorek, 2009). Students with visual impairments have the ability to master the same high-order science concepts as their sighted peers if accommodations are provided (Jones et al., 2006).

In order to help students with disabilities learn science, it has been found that they can benefit from informal learning experiences that allow for learning through alternative modalities (Melber and Brown, 2008). However, these students may have limited experience in informal settings due to transportation issues, family funds, or health services schedules. Melber and Brown (2008) suggest informal learning experiences in curricula for students with disabilities can be used as science-enrichment experiences to support formal classroom instruction. These experiences can not only benefit students with disabilities, but also their peers (Rye et al., 2012).

The limited research-based science teaching methodologies published for students with visual impairments is a further complication. Many manuals exist to explain how to teach science to students with visual impairments (Hadary and Cohen, 1978; Willoughby and Duffy, 1989; Dion et al., 2000; Koenig and Holbrook, 2000; Kumar et al., 2001). However, very little research has been conducted to determine the effectiveness of these curriculum materials (Linn and Peterson, 1973; Long, 1973; Linn and Their, 1975; Struve et al., 1975; Waskoskie, 1980; Erwin et al., 2001; Jones et al., 2006; Jones et al., 2008; Wild and Trundle, 2010a, 2010b; Rule, 2011; Wild et al., 2012). Inquiry-based instructional techniques have been reported for teaching the concepts of scale, environmental science, seasonal change, space, and sound to students with visual impairment (Jones et al., 2008; Wild and Trundle, 2010a, 2010b; Rule, 2011; Wild et al., 2012). In the search for articles related to geology and the students with visual impairments, three articles were found (Travis, 1990; Asher, 2001; Rule, 2011) describing curriculum modifications. Only one article was found to contain research related to the curriculum (Rule, 2011). Therefore, the purpose of this paper is to explore teaching strategies in geoscience for use with students having visual impairment as well as present research about the students' conceptual understandings of geosciences concepts before and after participation in a field-based camp.

GEOLOGY MISCONCEPTIONS

Examining student knowledge about a topic has been used to decide where to start the instruction (Rieback and

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Gautier, 2005). Therefore, we began our study by examining the misconceptions of geosciences concepts in the general education community. Students at all levels demonstrate misconceptions relating to the geological concepts of watersheds (Shepardson et al., 2005), climate change (Riebick and Gautier, 2005), plate tectonics (Libarkin, 2005; Sibley, 2005) and Earth surface temperatures (Salierno et al., 2005). Other students were found to have confusions regarding how the Earth's age is calculated, and when humans, dinosaurs, and other life forms appeared on Earth (Libarkin, 2005). However, no research could be found that described the geoscience misconceptions, targeted by the curriculum used at this camp, of students with disabilities, including visual impairment.

PURPOSE

The purpose of this qualitative study was to describe and understand the conceptual understanding that students with visual impairments have about the geologic concepts of the Earth's systems before and after an informal field-based science camp. The concepts considered were based upon the educational standards for this age level of students (National Research Council, 2012) and included: Earth's planetary history, properties and movement of water in shaping the Earth's surface, and the impact of living organisms on the Earth's processes and structures. In addition, we describe the instructional techniques used during the camp that appeared to be beneficial to students with visual impairments participating in an informal unit on geology.

METHODOLOGY

Setting

The research study was conducted during a weeklong, 5-day summer camp at a state residential school for the blind in the midwestern United States. Students arrived at camp for registration Sunday evening and were housed at the school for the entire week of camp. The theme of the camp was geology and Earth systems. Instruction and field experiences on the geology concepts lasted from approximately 8:00 a.m. to 4:00 p.m., Monday through Thursday, and Friday from 8:00 a.m. to noon. Students spent their evenings doing traditional social activities such as swimming, attending a movie, going roller skating, etc. All students returned home on Friday afternoon.

Participants

Students

The geology camp was advertised on the website of a midwestern residential school for the blind. Any high school student with any type of visual impairment in the state was eligible to apply to attend the camp. Eighteen students attended the camp but only sixteen students with visual impairments had parental permission to participate in this study. However, one student had limited English and therefore her answers were eliminated from the data set. The participants were aged 13–18 and were in grades 8–12. Of those students whose data were coded, seven were male and eight were female. Students' visual impairments covered a gamut of situations ranging from blindness to conditions resulting in low vision. The variety of visual impairments necessitated the production of instructional print materials in both large print and Braille. In addition to having a visual impairment, several students had additional disabilities. Specific data on visual impairment conditions and additional disabilities were not collected due to stipulations in the research review process.

Teachers

In order to help with the field-based science experiences, multiple teachers were involved with this camp. One camp director and an assistant developed the schedule and planned all pre- and post-field-based activities, bus routes, and arranged for the field-based instructors. The camp director and assistant were science and math teachers from the residential school who were assigned by the school to run the camp. Two teacher interns from a collegiate teacher preparation program for teachers of students with visual impairments also attended camp and provided assistance as needed. These students volunteered to be part of this camp in order to earn student teaching hours toward certification. Three orientation and mobility interns from a collegiate preparation program for certified orientation and mobility specialists attended camp and provided assistance to students when travelling in various terrains. Similarly, these interns volunteered to be part of this camp in order to earn internship hours toward certification. None of the interns had prior experience working with students with visual impairments in field-based science learning experiences.

Curriculum

Students were exposed to a variety of lessons both in class and out in the field involving the theme of telling the history of the Earth through geologic evidence.

Day 1

The first day of camp provided instructional time from 9:00 a.m. to 3:30 p.m. The day began with ice-breaker activities so that the students could meet and learn more about each other. After the first activity, the researchers conducted the preinstructional interviews. The instruction then followed with an introduction to the rocks and minerals commonly found in the state in which the students were attending camp. This was accomplished through exploring rock and mineral samples from a kit developed by the State Department of Natural Resources. This was a guided inquiry experience for students. Students examined the samples and measured the mass with a digital scale and volume using water displacement. Using this data, the students calculated the density of each rock and mineral. Scales and calculators adapted for students with visual impairments had audible as well as visual readouts. Students read instructional text accompanying the kit in either large print or Braille format. Small groups of students were assigned to become "experts" of either a rock or mineral through collecting investigatory data and reading the informational text. Afterwards, the students orally presented the information that they found to the class. The camp director facilitated a class discussion in which students compared and contrasted the information discovered.

The next lesson centered on an interactive discussion about cave and cavern formation and the properties of limestone, a major rock found in the state and explored later in the week. The discussion was enhanced by a Smart Board presentation by the camp director. The large images of caves and caverns were thoroughly described for the students who were unable to see them. Students also had readings provided in large print and Braille adapted from materials provided by the State Department of Natural Resources. Students took turns reading the information before the teacher summarized each section and questioned students for comprehension. Students conducted a confirmatory experiment with limestone samples and vinegar to experience firsthand how limestone can be easily dissolved by a weak acid.

The last lesson focused on fossils and geologic time. First the students read from materials provided by Caesar Creek State Park and the Division of Geological Survey regarding geologic time and geologic periods. Relief maps of the state were provided in tactile format to students to explore and supplement the print materials. Classroom discussion led by the camp director centered on student understanding of terms and concepts. Students had the opportunity to model fossil formation by pressing different shells and animal shapes into soft clay. Each student could then feel the impression made in the clay by the object. The camp director explained that this simulated the first step in how some fossils were formed.

Day 2

Day 2 began at 8:00 a.m. and started with a trip to Caesar Creek State Park. The students travelled by bus from the camp site to the park. On the way to the park, the camp director pointed out landscape features and tied them to the previous day's discussion about geologic time and changes to surface features. An engineer from the Army Corps of Engineers met the students at the welcome center. She provided an overview of the geologic focus of the park, including how events during different time periods determined what they would find in the park. A large number of fossil samples were provided for the students to tactually explore. Fossils were passed around and students were given hand-over-hand assistance as needed to feel the fossils and differentiate one from another. Park rules for fossil hunting and safety were discussed as this was the next activity. Students spent the remainder of the morning hunting fossils in the state park with the help of the teachers, the orientation and mobility specialists, and the engineer. Informal conversations among the students, teachers, and the engineer clarified student understandings about the wide variety of fossils present and how they were formed. Students were allowed to keep a fossil that they found as long as they could carry it out in the palm of their hands.

After the morning trip to Caesar Creek and lunch, the students travelled to the Orton Hall Geological Museum. There the students were met by the museum's curator who explained the history of geologic time periods and what evidence from those periods could be found in the state. Throughout the presentation, students were encouraged to tactually explore rocks, fossils, and models of animals found in the state at different periods of geologic time. Teachers and orientation and mobility specialists assisted students with hand-over-hand exploration of the different items. The curator used very descriptive language to explain those items that students could not touch, such as a skeleton of a 7-foot-tall giant ground sloth, *Megalonyx jeffersoni*. Students returned to camp around 4:00 p.m. for a snack and nighttime social activities.

Day 3

Wednesday began at 8:00 a.m. with a bus trip to the Hocking Hills, an area of the state well known for caves and caverns. The first stop was Ash Cave. Students hiked through the woods to the large cave on an accessible path. The ground surface of the path and cave was mixed gravel and sand. Once inside the cave, the teacher read information from a brochure provided by the State Department of Natural Resources to the students. The information explained the geologic composition of the area, how the cave was formed, the impact of ongoing weathering of the rock, and the historical uses of the cave. Students walked around the cave feeling the uneven surface of the walls and shallow crevasses. They reveled in the echoes of their voices inside! Students also explored a small waterfall near the cave by venturing out onto the rocks and putting their hands under the waterfall to feel the water splash onto the palms of their hands.

The second stop was a location known as Rock House. Teachers and orientation and mobility specialists lead the students through a half mile trek through the woods that involved clambering over fallen trees and descending downward into a deep ravine. Access to the cave was achieved by climbing up steps carved into the rock face by ancient peoples. Students' ascent to the cave was carefully monitored by all adults on the trip, including the researchers. Once inside the cave, students explored the shallow tunnels within the sandstone structure. Students were given the help of an aide to walk around the cave while exploring it tactually. Students felt the walls of the cave, and listened to the echo of their voices comparing the size of Rock House to Ash Cave. Some students climbed up a few small outcrops within the cave to understand the height of the walls of the cave. The camp director answered students' questions and continuously made connections between the print material provided by the Department of Natural Resources and the students' actual experiences in the cave.

The third stop of the day was to Lake Logan for recreation. This was a break in instruction for the students, free of curriculum content. The remainder of the day was spent swimming in the lake and lounging in the sunshine. Students also had the thrilling option to drive a houseboat owned by the residential school's principal. The principal took small groups of students and adults in the boat to the far end of the lake and verbally guided the students while they piloted the boat. One student gleefully commented, "This is the best day of my life!" Students returned to the school for evening activities by 5:00 p.m.

Day 4

Thursday began at 8:00 a.m. with a bus trip to Ohio Caverns. Students were met by a tour guide who provided information about caverns. She explained that caverns were underground spaces caused by the gradual flowing and dripping of water over long periods of time. She stated that the difference between caverns and caves is that caverns were completely underground, a distinction not shared by many geologists. The guide prepared the students to see stalactites and stalagmites by describing how they are formed and the various common shapes. She concluded her above ground talk with a discussion about the impacts of humans on the caverns. The students descended into the cavern by walking on a well prepared pathway. Inside the cavern, descriptions of all visual information were given in great detail to the students by the tour guides and the camp adults. Unfortunately, due to preservation concerns, students were not permitted to feel the sides of the caverns and the rock formations within the cavern. Instead, they were directed to listen carefully for the sounds of dripping water and the muted echoes of their voices. The musty smell of the cavern was also a highlighted sensory experience. Navigating students across the uneven wet floor required the close attention of the supervising adults. The tour guide shared a number of local folklore stories about specific stalagmites in the cavern. A trip to the souvenir shop completed the cavern excursion.

After the cavern tour and lunch, the students were then taken to a nearby state park that features a bog. A tour guide met the students and took them into a nature center that was filled with plant and animal artifacts from the bog. He explained the ecology of the bog and how the plants and animals that lived there were dependent upon the resources within the bog for their survival. He also explained how the plants and animals contributed to the structure of the bog. The students had opportunities to tactually explore plant and animal artifacts such as feathers, seeds, nests, turtle shells and antlers. They also handled taxidermy specimens of song birds and other the animals that live in the bog. The guide discussed the human impact on the bog and the preservation efforts by concerned citizens. Students walked through the bog on a raised wooden walkway while the tour guide pointed out salient features. Camp adults provided navigational assistance as needed. Students were so interested in the bog animals that after the walk the guide brought out a few live garter snakes for the students to handle. Afterwards, students returned to camp by 4:00 for dinner and evening activities.

Day 5

The instructional period for day 5 lasted from 8:00 a.m. until 12 noon to allow travel time home for the students. During the shortened instructional time period, students reviewed all of the material they had learned during camp. The director summarized each day through an oral recap of the trips that were taken and the Earth system curriculum explored during camp. Her talk highlighted the geologic history of Earth in general and specific ramifications within the state. Students were asked to provide examples of the ways they learned that the Earth was changing, how water had shaped the landscape, in particular referring to the caves and caverns that the students explored. They were prompted to review the ways that the Earth's systems interact and how living organisms had altered the Earth's processes and structures.

After the review, the students worked on an activity to create a model of the Earth's rock layers. Students put edible representations of rock and mineral deposits (cereal, candies, gummies, etc.) into premixed cake batter and baked the mixture in the school's home economics classroom. The kitchenettes in the classroom are designed to be accessible for students with visual impairments with tactile knobs on the ovens and labeled drawers for cooking utensils. While the cakes baked, students produced a written explanation of what each edible deposit component in their rock layers represented. The computer lab at the school was utilized for this assignment since the computers were already loaded with accessible software for students with visual impairments. Also, during the baking time the researchers conducted the postinstructional interview with individual students.

Materials used throughout the curriculum include Braille and large print reproductions of written materials from the U.S. Department of Natural Resources and the Ohio Department of Natural Resources. These adapted materials were produced on site at the school. The field locations visited—Ohio Caverns, Caesar Creek State Park, Cedar Bog State Park, and the Orton Geologic Museum—each provided an expert who delivered presentations and guided the explorations of the students. These experts routinely provide presentations to the general public on the same topics. The camp director used published material to teach concepts at the field locations that did not provide expert guides. Lab materials utilized at the school included rock and mineral kits, beakers, audible digital scales, and calculators. Classroom discussions were supported with a Smart Board, tactile topographic maps, modeling clay, and small objects to press into the clay such as seashells. The Earth layer modeling activity required these supplies: cake batter, cereal, candies, accessible ovens, and baking utensils. A computer lab with accessible software was needed by students to write an explanation of their layering model.

Each lesson presented to the students was aligned to the Ohio Revised Science Standards and Model Curriculum (Ohio Department of Education, 2011) and generated from curriculum resources published by the U.S. Department of Natural Resources, Army Corps of Engineers, Ohio Department of Natural Resources, Division of Geological Survey, as well as the oral presentations given by experts at the field-based locations.

The director of the camp commented in an informal interview that she felt she had accomplished the goals of the camp. She wanted the students to experience active learning in an environment outside of their comfort zone. She aspired for the students to be exposed to field-based geology, something she felt many students with visual impairments did not have the opportunity to experience in their home schools. The director also wanted the students to learn directly from experts in the field to expand their understanding of what scientists really do. Lastly, the director expected the students to learn geologic concepts that are embedded in the Science Content Standards.

Data Collection

The data for the project was qualitative in order to allow for multiple data points and to allow researchers an opportunity to better understand the knowledge presented by each student. The data collected by three researchers included using semistructured pre- and postinstruction interviews of students; classroom and field-based observations; and document analysis of field notes. Student interviews were video recorded and then transcribed. Classroom instruction was documented through video recording and written field notes. Attention to the interaction of the camp director and students was noted, especially student responses to teacher questions and student questions posed to the teacher/presenters. Field notes also focused on the presentations of the field experts in order to compare their presentations to the planned curriculum and state standards. All data points were used to monitor student response to instruction, fidelity of the curriculum implementation, and for triangulation of the data.

Student Interviews

The semistructured interview centered on five questions all based upon key middle and high school Earth science concepts identified in *A Framework for K–12 Science Education: Practices, Cross Cutting Concepts, and Core Idea* (National Research Council, 2012). Preinstructional interviews were conducted the first day of camp prior to any instruction and a postinstructional interview on the last day of camp after all instruction was completed. Each student was asked the same series of questions in the pre- and postinterviews.

Questions included:

1. How do people reconstruct and date events in Earth's planetary history?
2. How and why is the Earth constantly changing?
3. How do the major Earth systems interact?
4. How do the properties and movements of water shape Earth's surface and affect its systems?
5. How do living organisms alter Earth's processes and structures?

Data Analysis: Constant Comparative Methodology

Constant comparative analysis was utilized to analyze the data. The constant comparative method includes multiple steps such as comparison of data within a single interview to a code framework, comparison of interviews within the same group to the coded framework, and comparison of interviews of different groups to the coded framework (Boeije, 2002). Constant comparative analysis has been used with other science content research for students with visual impairments including seasonal change (Wild and Trundle, 2010b) and sound (Wild et al., 2012). Before data analysis began, a coding framework was developed based upon the knowledge presented in the recommended standards and literature. This served as a "partial framework" for coding (Glasser and Strauss, 1967, p. 45). This framework provided a starting point for the codes that were used during data analysis. Creation of the initial categorization of alternative and scientific conceptions was based upon the Trundle et al. (2002, 2007a, 2007b) system in which conceptual understandings were divided into six major categories: scientific understanding, scientific fragments, scientific with alternative fragments, alternative, alternative fragments, and no understanding. Alternative fragments with scientific fragments was later added in order to code those students' responses that had more alternative understandings than scientific, but still had a few scientific understandings. Science standards in *A Framework for K–12 Science Education: Practices, Cross Cutting Concepts, and Core Ideas* (National Research Council, 2012) were utilized to determine scientifically accurate responses.

Field notes were analyzed in order to assess fidelity of the curriculum content and to assess how state standards were addressed in the curriculum. These notes were also analyzed to determine if the curriculum met the goals of the director of the camp.

Trustworthiness

Member checking, triangulation, and interrater reliability were all used throughout this study in order to determine trustworthiness. Member checking, as defined by Seidman (2006), was used to confirm student answers by asking probing questions and researchers rephrasing of student responses in order to assess statements of students who provided vague or inconsistent answers. These follow-up questions served to ensure that researchers understood student answers and properly interpreted student responses.

Triangulation of the data was used to cross-check data by collecting field notes, student responses to instructional questions, interview responses, classroom observations, and analysis of participation. Student responses were found to be consistent through the triangulation and member checking methods.

Three researchers worked together to code all of the data. Each researcher coded the data independently based upon the established coding rubric. The researchers had 96% agreement after each student interview was initially coded and 100% agreement after a short discussion.

STUDENTS' CATEGORIZED RESPONSES

Scientific

In order for a student's response to be considered scientific, students' answers had to align with the Earth science content presented in *A Framework for K–12 Science Education: Practices, Cross Cutting Concepts, and Core Ideas* (National Research Council, 2012). Students who responded with some element listed in the standards were noted and given credit for a partial scientific understanding as described by Trundle et al. (2002, 2007a, 2007b). For the first question, How do people reconstruct and date events in Earth's planetary history? students needed to state that people are able to reconstruct and date events in Earth's planetary history through examining rock layering, fossils, erosion and weathering, ice core patterns, glaciation evidence, and radioactive decay and isotope content of rocks. For the second question, How and why is the Earth constantly changing? students must have described the interaction of the geosphere, hydrosphere, atmosphere and biosphere, energy flow through the systems, matter recycling, and tectonic plates. The same answers indicated for question 2 could be used for question 3: How do the major Earth systems interact? The fourth question, How do the properties and movement of water shape Earth's surface and affect its systems? required students to describe thermal heat transfer, glaciers, ocean currents, the water cycle, and water movement in terms of downhill flow causing major erosion or underground formations. Students should have also described water's capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. The last question asked students, How do living organisms alter the Earth's processes and structures? Responses should have included living organisms alter the weathering and erosion of landforms, alter the soil composition, affect the distribution of water in the hydrosphere, and provide dynamic feedbacks between the biosphere and other Earth systems.

The following excerpt is from a transcript of the postinstruction interviews. This small excerpt shows how the researchers coded scientific understandings of students. The researcher questions and responses of the students are given with the code in parentheses.

Researcher: How do people reconstruct and date events in Earth's planetary history?

TABLE I: Misconceptions and explanations of geologic concepts by students with visual impairments.

Misconception	Explanation	No. of Students Describing Phenomenon in Preinstruction Interview	No. of Students Describing Phenomenon in Postinstruction Interview
People	Things that people do can alter Earth's processes and structures and they can reconstruct events in Earth's planetary history.	7	7
Seasons	Seasons are the reason for Earth's constant change.	4	2
Wobble	The Earth moves back and forth and that movement causes it to constantly change.	1	1
Water pressure	Too much water pressure on Earth can cause plates to move causing floods and tsunamis effecting Earth's surface and its systems.	1	0
Tree rings	Tree rings are used to date events in Earth's planetary history.	1	0
Killing	Animals killing other animals can cause the changes in the major Earth systems and the way they interact.	0	1
Behavior	Animal behavior can alter the Earth's processes and structures.	0	1
Revolve	The revolution of the Earth causes it to constantly change.	3	2
Rotation	The rotation of the Earth causes it to constantly change.	3	4
Timelines	Timelines are used to reconstruct and date events in Earth's planetary history.	2	1
Food chain	Food chains can alter the Earth's processes and structures by eliminating other species.	1	1
Research	People find studies or study other studies to understand the events in Earth's planetary history.	1	1
Habitat	Earth's major Earth systems are interacting through interactions of different habitats.	1	1
Museums	Museums reconstruct and date events in Earth's planetary history.	0	2
Climate change	Climate change is causing the Earth to constantly change.	0	2
Life cycle	Stages in lives of animals cause the major systems of the Earth to interact.	0	1
Finite	The amount of erosion that can occur is finite and therefore can stop water from shaping Earth's surface and affecting Earth's systems.	0	1
Life	People provide life to the Earth and can alter Earth's processes and structures.	1	1
Water marks	Water marks on walls of rocks can tell you about events in Earth's planetary history.	0	1
Location	Depending on the geographic location on Earth where water is located depends on the movement and how it interacts to shape the Earth.	1	0
Weather	The Earth is constantly changing due to weather.	1	0

Student: Well, they reconstruct by fossils (scientific). They, like, analyze and they do tests on fossils to see how far back in time scale they went.

Researcher: How do the properties and movement of water shape Earth's surface and affect its systems?

Student: Tides and waves when they come up against the shore they help shape (scientific) . . .

Researcher: Did you see any instances this week that you could use as an example . . .

Student: When we went to the caverns that used to be, um, water and it did really well shaping it, it created tunnels (scientific).

Alternative Conceptions

Numerous alternative conceptions existed both in the preinstruction interviews and the postinstruction interviews

TABLE II: Conceptual understanding pre- and postinstruction.

Category	Preinstruction	Postinstruction
Scientific	0	0
Scientific fragments	1	1
Scientific with alternative fragments	6	11
Alternative	0	0
Alternative fragments	1	0
Alternative fragments with scientific fragments	5	3
No understanding	2	0

(see Table I). Alternative concepts are defined as any conceptual understanding that does not agree with the scientifically accepted norms (Atwood and Atwood, 1996). The most common misconceptions were that people were the agent of change, and also that the revolution and/or rotation of the Earth caused change through making systems interact.

An example of a student with an alternative conception is found below. A transcript of the researcher's questions and the answers provided by the student is presented. The coding of the alternative conception can be found in the parentheses.

Researcher: How do people reconstruct and date events in Earth's planetary history?

Student: Well . . . like if they find studies of, like, things, like, of the planet and they could, like, just study them (alternative conception related to research) . . . and if they want to display it they can put it in a timeline or something (alternative conception related to timeline).

Researcher: How and why is the Earth constantly changing?

Student: Because the Earth rotates on its axis and space and Earth orbits the sun so it rotates round the sun, it goes around the sun and changes time . . . on the axis what happens is it rotates all around (alternative conception related to rotation and revolution).

RESULTS

Preinstruction

Prior to instruction, two students had no understanding of geology and Earth systems (see Table II. Note: All students are listed with pseudonyms). One student had only alternative understandings of the concepts presented. Of the remaining 12 students, 6 students held more alternative understandings than scientific understandings, and 5 students held more scientific understandings than alternative understandings. One student held only scientific fragmented understandings. The misconceptions held by students included (1) people alter the Earth's process and structures and can reconstruct events in Earth's planetary history, (2) seasons cause the Earth to constantly change, (3) the Earth's movement causes change, (4) too much water pressure on Earth can affect the Earth's surface and systems, (5) tree rings are used to date events in Earth's planetary history, (6) revolution and rotation of the Earth causes change, (7) timelines are used to reconstruct and date events, (8) food chains can alter the Earth's processes and structures, (9) people rely on research to understand the planetary history, (10) weather causes the Earth to constantly change, (11) people provide life to the Earth and can alter the Earth's processes and structures, (12) habitats cause interactions of Earth's systems, and (13) depending on the geographic location on Earth where water is located depends on the movement and how it interacts to shape the Earth.

TABLE III: Pre- and posttest results by student.

Name	Preinstruction No. of Scientific Understandings	Postinstruction No. of Scientific Understandings
Brad	2	6
Ross	4	6
Brittany	4	7
Bob	5	8
Caden	0	4
Erica	0	3
Hayden	1	6
Jaimie	4	9
Kyra	2	5
Laura	8	6
Sarah	1	3
Simon	3	11
Tara	0	1
Tyson	1	3
Roger	1	4

Postinstruction

After participation in the curriculum the majority of the students, 11 of the 15 total students, held some scientific understandings with some remaining alternative understandings. One student held fragmented scientific understandings only and the remaining students had more alternative understandings than scientific understandings. The misconceptions held by students after instruction include (1) water marks on walls of rocks tell you about events in Earth's planetary history, (2) people provide life to the Earth and can alter the Earth's processes and structures, (3) the amount of erosion can affect Earth's systems, (4) life cycles of animals cause systems of Earth to interact, (5) climate change is causing the Earth to change, (6) museums reconstruct and date events in Earth's planetary history, (7) habitats cause interactions of Earth's systems, (8) people alter the Earth's process and structures and can reconstruct events in Earth's planetary history, (9) people find studies or study other work to understand Earth's planetary history, (10) seasons cause the Earth to constantly change, (11) the Earth's movement causes change, (12) revolution and rotation of the Earth causes change, (13) timelines are used to reconstruct and date events, (14) food chains can alter the Earth's processes and structures, (15) people rely on research to understand the planetary history, (16) animals killing other animals can cause changes on Earth, and (17) animal behavior can alter Earth's processes and structures. See Table III for specific pre- and posttest results for each student.

CONCLUSION

Students arrived at camp burdened by more alternative understandings of Earth science than scientific. We attribute those misunderstandings to a lack of intentional instructional experience in Earth science. Even though the participants were middle school and high school aged, they showed little evidence of using geologic reasoning to connect field observations to the big concepts of geology. One week of inquiry-based lessons was not enough support or time for the students to apply new learning to their existing knowledge and reorganize their understanding to become wholly scientific. We observed an increase in scientific responses, however, they were held simultaneously with the alternative concepts. This duality of understanding may be a preliminary stage to be resolved later after additional school-based experiences. We anticipate that the rich sensory experiences and interpretations of them by content experts during the informal environment of a summer camp will benefit the students when they receive further formal classroom instruction. It appears that the curriculum met the goals of the camp director as well as provided instruction based upon the state and national science standards. However, not all standards were covered in this curriculum. Participation in the curriculum lead to an overall increase in scientific understandings but appeared to have not helped students with their alternative understandings.

LIMITATIONS

This study focused on a group of students with visual impairments who completed a field-based curriculum during a week of camp focused on concepts of geology. The students represented a variety of grade levels from diverse locations throughout the state and therefore may not represent the larger population of students with visual impairments. Due to stipulations in the approved research protocol, specific data relating to additional disabilities, eye conditions, and academic performance were unable to be collected. This may limit the interpretation of the instruction techniques used and its impact on students' postinstruction understandings. Due to a lack of randomization, we cannot account for additional factors that may have contributed to the students' conceptual change. Therefore, the results cannot be confidently generalized.

Prior to the research study, researchers could not be completely aware of the instruction that was to be presented to the students due the reliance on field experts. The researchers had no way of knowing the exact content the field experts would deliver upon arrival at various locations. Researchers were only told of the type of content that would be delivered. Therefore, not all of the mandated science curriculum standards were delivered to students and could have contributed to the lack of scientific answers provided by the students.

IMPLICATIONS AND RECOMMENDATIONS

Students in this study struggled with conceptual understanding of geologic concepts (Libarkin, 2005; Riebick and Gautier, 2005; Salierno et al., 2005; Shepardson et al., 2005; Sibley, 2005), specifically that of the Sun–Earth relationship contributing to geologic change similar to their sighted peers (Salierno et al., 2005) and as documented in previous research with students with visual impairments (Wild and Trundle, 2010b). However, these students exhibited some unique misconceptions unrelated to any current research. Those misconceptions include (1) people contributing to Earth's processes; (2) water pressure causing tectonic plates to move; (3) using tree rings to date planetary history; (4) behaviors of animals, such as animals killing other animals, causing changes in Earth's systems; (5) using research and museums as a way to reconstruct and date Earth's planetary history; (6) climate change causing constant change on Earth; (7) life cycles causing Earth's systems to interact; (8) a finite amount of erosion interacting with water to shape and affect Earth; (9) water marks tell about events in Earth's history; and (10) location of water depending on interactions on Earth. These misconceptions support the research findings of previous research in that students with visual impairments can have unique misconceptions of scientific concepts not documented with sighted peers (Jones et al., 2008; Wild and Trundle, 2010a, 2010b; Wild et al., 2012).

One week of instruction on these geologic concepts did not provide the support or time needed for students, who attended the camp with different educational experiences in geology, to apply new learning to any existing knowledge they may have had and be able to reorganize their understanding into a scientifically accurate understanding defined by state and national standards. The knowledge and field experiences from this camp should be used and further built upon in formal school-based education environments.

This camp utilized the support of veteran teachers, the directors of the camp, and teacher interns. The interns provided necessary support in orienting the students to the various field-based settings, providing hand-over-hand assistance to materials explored, and providing guided assistance in difficult terrain. Without the support of the interns it would have been nearly impossible for full participation in the camp by all students.

In order to ensure that all students are learning scientific concepts accurately, future research should be conducted on teaching methodologies to help students overcome these misconceptions in geoscience education. Field-based work and formal education experiences together should be examined in the future to determine the effectiveness of teaching geologic concepts. Additional inquiry-based geoscience curricula should be researched, as inquiry-based methodologies have been shown to be beneficial to students with visual impairments in the past (Erwin et al., 2001; Wild and Trundle, 2010a, 2010b; Wild et al., 2012).

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