Utilizing an Artificial Outcrop to Scaffold Learning Between Laboratory and

Field Experiences in a College-Level Introductory Geology Course

by

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ABSTRACT

Geologic field trips are among the most beneficial learning experiences for students as they engage the topic of geology, but they are also difficult environments to maximize learning. This action research study explored one facet of the problems associated with teaching geology in the field by attempting to improve the transition of undergraduate students from a traditional laboratory setting to an authentic field environment. Utilizing an artificial outcrop, called the GeoScene, during an introductory college-level non-majors geology course, the transition was studied. The GeoScene was utilized in this study as an intermediary between laboratory and authentic field based experiences, allowing students to apply traditional laboratory learning in an outdoor environment. The GeoScene represented a faux field environment; outside, more complex and tangible than a laboratory, but also simplified geologically and located safely within the confines of an educational setting.

This exploratory study employed a mixed-methods action research design. The action research design allowed for systematic inquiry by the teacher/researcher into how the students learned. The mixed-methods approach garnered several types of qualitative and quantitative data to explore phenomena and support conclusions. Several types of data were collected and analyzed, including: visual recordings of the intervention, interviews, analytic memos, student reflections, field practical exams, and a pre/post knowledge and skills survey, to determine whether the intervention affected student comprehension and

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interpretation of geologic phenomena in an authentic field environment, and if so, how.

Students enrolled in two different sections of the same laboratory course, sharing a common lecture, participated in laboratory exercises implementing experiential learning and constructivist pedagogies that focused on learning the basic geological skills necessary for work in a field environment. These laboratory activities were followed by an approximate 15 minute intervention at the GeoScene for a treatment group of students (n=13) to attempt to mitigate potential barriers, such as: self-efficacy, novelty space, and spatial skills, which hinder student performance in an authentic field environment. Comparisons were made to a control group (n=12), who did not participate in GeoScene activities, but completed additional exercises and applications in the laboratory setting.

Qualitative data sources suggested that the GeoScene treatment was a positive addition to the laboratory studies and improved the student transition to the field environment by: (1) reducing anxiety and decreasing heightened stimulus associated with the novelty of the authentic field environment, (2) allowing a physical transition between the laboratory and field that shifted concepts learned in the lab to the field environment, and (3) improving critical analysis of geologic phenomena. This was corroborated by the quantitative data that suggested the treatment group may have outperformed the control group in geology content related skills taught in the laboratory, and supported by the GeoScene, while in an authentic field environment ($p \leq 0.01$, $\delta = 0.507$).

DEDICATION

This work is entirely dedicated to: my children; Vivian, Josh, and Jake, who are my inspiration; and my husband, Beau, who is everything else. Their genuine curiosity and love of learning consistently reminded me why I chose this crazy endeavor. Their endless supply of energy, humor, and love reminded me to live my life, with them, as I progressed through the degree. Their support and understanding allowed me to complete this project with my soul intact. Jake offered me this bookmark as I struggled through my last winter break trying to finish this degree, it is indicative of all the reasons my family amazes and inspires me. I, therefore, offer it to the reader of this dissertation: cut out and fold along the dotted line.

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INTRODUCTION AND CONTEXT

On a sunny summer's day in 1997, a bright young woman from France, named Juliet, was entering the United States to follow her dream to pursue an advanced degree in geology. She had prepared for this opportunity for many years, beginning her coursework in earth sciences in middle school, and maintained a 4.0 grade point average throughout her entire academic career. She had also been studying the English language since she was six years old, and was fluent both written and verbally. Though she was raised with little money and had not traveled extensively in her life, she was not intimidated to be out on her own for the first time half way around the world.

Once in the arrival gate at JFK International Airport in New York, Juliet's dreams nearly shattered before her eyes. She could read all the English signs without a problem, but no one seemed to be able to understand her, and she could not understand them either!   How could this be? She had been speaking English in school for nearly fifteen years and had always been understood by her instructor and classmates. Likewise, she could always understand what they were saying to her. But now it seemed as though she had never studied the language at all. She gathered her belongings and sat in a corner at the baggage claim and cried. Unable to return home, she pulled herself together and continued to her final destination in Arizona, because she simply felt she had no other alternatives.

Though Juliet continued to struggle with English for a few months after her arrival, she overcame her issues with the language and went on to receive her

doctorate. Reflecting on this experience years later, Juliet identified where her preparation had fallen short. In all the years studying English, she never had authentic experiences speaking and interacting with native U.S. English speakers in an environment outside the classroom. So, when Juliet came to America, she felt completely unprepared to be successful in the necessary practical conversations with native speakers.

The vignette of Juliet is particularly compelling, because it is not a unique educational experience. The objective of schooling is to educate individuals so they may assume productive roles in society (Arum, Beattie, & Ford, 2011). How can this be accomplished without helping students to transition from the classroom environment to the applications of the real world? Duffy and Jonassen (1992) argued that knowledge without context does not provide the skills to apply understandings to authentic tasks, because the authentic environment is too complex to determine how and when the concept is used. There have been general innovative reforms that help to bridge the gap between schooling and application for students between high school and college, but these types of reforms could be applied within the confines of individual course curriculum (Richmond, 2010).

Professional Context

I teach introductory geology courses at Arizona Community College[1] (ACC), one of ten community colleges in the Arizona Community College District[1] (ACCD), which is one of the largest providers of higher education in the

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[1] This is a pseudonym.

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United States (Arizona Community College District, 2010). Most students at ACC are taking their general education requirements before they continue on to a four-year institution, and the majority of students self-identify themselves on the first day of class as those that enrolled to fulfill their science requirement in the easiest way possible (Cohen & Hughes, 2009).

In addition to providing a foundation for geology majors, the primary focus of this course is to pique students' interest in geology, give them knowledge of the science, and help them develop some basic geologic interpretive skills that can be applied to the world around them. For most non-science baccalaureate degrees in Arizona, the introductory geology class will fulfill one of only two science courses students take during their entire college career (Aztransfer.com, 2010). Some of these students may move on to become elementary school teachers, who typically have low self-confidence in their ability in math and science (Lewis, 2008). These elementary education students go on to take science methods courses, but typically do not adopt learner-centered, discovery-oriented, constructivist pedagogies most often associated with the learning of science (Riggs & Kimbrough, 2002). Because these are the students that will go on to shape our world and teach our children, I am motivated to help students make deeper connections within the content of geology, gain confidence in the science, and successfully apply concepts to authentic geological situations in a single introductory college level course.

Throughout my experience teaching geology at a community college, students do not transition their conceptual understanding well from the laboratory

classroom to the field environment, and overcoming this hurdle has become one of my most important goals in teaching introductory geology courses. For example, there have been many times where students could easily identify a rock in a laboratory, but could not identify the exact same rock in a field setting. This fact is at times surprising, amusing, and/or frustrating. Why don't they get it? Speaking with other colleagues in ACCD, they identify similar issues. Students who have gone on to become geology majors over the years have voiced similar concerns, even in upper division geology classes. This reminds me of Juliette's experience. Are we missing a critical step from theory to authentic application?

Previous Action Research

Two previous cycles of research have informed this study. The first occurred during the fall semester of 2009 and concentrated on improving student gains in the field environment utilizing the *GeoScene*[2]. The GeoScene is an artificial outcrop; a collection of rocks arranged into geologically complex features designed to simulate a fictitious geologic region, located in the landscaping outside the laboratory classroom at ACC (Figure 1).

Figure 1

GeoScene at Arizona Community College

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[2] This term was created by the author.

This pilot study explored whether students (N=18) who applied laboratory concepts directly to the GeoScene performed better in a field setting, as well as how confident they felt performing the necessary tasks in the field. The study involved random assignment sampling within a single class, with a treatment group applying laboratory concepts to the GeoScene. The students were assessed utilizing a post-test only field test, as well as a survey on overall student confidence in the field setting. A t-test was conducted and the results of the pilot study suggested that the students who had participated in GeoScene activities significantly outperformed students on the overall field assessment ($p \leq 0.01$). Due to the small sample size, an effect size was calculated to lend strength to the statistical significance (d=1.67). The treatment group also reported higher self-confidence in the field. From this pilot, it was suggested that the GeoScene was a potentially beneficial teaching and learning tool. The pilot began to suggest that the GeoScene did improve student performance in field environments, but no qualitative data sources were collected to support the conclusions and there was a very small sample size. The pilot was conducted to determine if any potential relationship existed between participation with the GeoScene activities and performance in a field setting only, determining how or why the change occurred was not within the scope of the study.

Tretinjak and Riggs' (2008) research suggests that authentic field experiences are important for undergraduate non-science majors, and that they cannot be replaced by virtual experiences, so the second round of action research focused on how field trips affected student attitudes toward the science rather than

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whether the GeoScene could be used as a replacement to true field experiences. The second action research project took place in the spring of 2010 and was designed to explore what role a field trip plays in a student's overall perception of geology. This pilot study (N=22) addressed the question of how field trips impacted the student's view of the relevance of geology to their everyday lives. This study utilized a mixed methods approach to determine the impact of a single local field trip to an authentic geologic feature. Students from an introductory geology course, that utilized a problem-based learning platform during the entire semester, were given a pre/post survey and reflective prompts to complete during a single field trip experience. Selected students were given semi-structured interviews based on their responses to the survey and reflective prompts.

The quantitative data was analyzed utilizing a t-test, and the qualitative data was coded for themes. Both data sources from the second pilot study suggest that even a single field trip can make course content more relevant, significantly increase interest in geology ($p \leq 0.05$), as well as increase student confidence in assessing geologic phenomena. This result is consistent with the findings from Boyle et al. (2007), who showed that fieldwork positively affected the affective domain of students. Ultimately, this study begins to suggest that field trips continue to be an essential part of the learning experience for students in geology and should continue to be a part of curriculum.

Introductory geology students at ACC struggle applying geologic concepts to a field environment. The initial pilot studies suggested that authentic field experience increases student interest in geology and perceived relevance of

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geology to their lives. The GeoScene experiences appear to have enhanced

student performance in authentic field settings. As a result, I was interested to

further explore the connection of the GeoScene as a transition between the

laboratory and field environments. The following chapter delves in to the

literature and background understanding related to pursuing this interest.

Chapter 2

REVIEW OF THE LITERATURE

Throughout this chapter, geology is defined and the theoretical

perspectives for teaching and learning the science are discussed. Additionally,

literature suggesting potential barriers to learning geology in the classroom and

field environment are highlighted and explored. The importance of this chapter is

paramount, because it grounded the research in the literature, and allowed a

deeper understanding of the hurdles faced by the researcher in terms of theoretical

and practical applications of the problem.

Defining Geology and Teaching Geology

Geology is the scientific study of the earth. Geology incorporates aspects

of physics, chemistry, astronomy, and biology to understand the complex

interactions of numerous systems and physical processes, in order to explain and

understand the present workings and history of the dynamic planet (Stanley,

2009). It is a system science, understanding the earth as a complex interaction of

inter-related components. As such, it is incredibly difficult to learn and

understand fully, and offers challenges to students and teachers alike.

Many scholars believe that teaching geology utilizing a holistic systems

approach, incorporating all the sciences, is the most beneficial for students, and

this approach has been the instructional paradigm since the late 1970's (King,

2008; Mayer, 2002, 2003; Mayer & Tokuyama, 2002). This approach has been

utilized throughout North America and Europe, with most successful

implementation of including pedagogies that incorporate hands-on, active and

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problem-based learning, and scientific field trips (Lee & Fortner, 2003; Mayer, 2002).

Within the discipline of geology, field trips represent a valuable and essential venue where students apply their laboratory and lecture content knowledge to the real world. The terms: field, field trips, field excursions, fieldwork, field experiences, field-based, and field studies are used interchangeably throughout the literature to refer to a scientific excursion to an authentic geologic setting, where rocks and geologic features are exposed in situ in their environment (Elkins, & Elkins, 2007; King, 2008; Mayer, 2002, 2003; Orion, 1993; Tretinjak, & Riggs, 2008). Field experiences are utilized to clarify and confirm the connections between theory and application in geology and related disciplines (Carter, 1993; Peterman, 2008; Scarce, 1997). Studies have shown that students involved in field experiences develop deeper understanding of geological concepts than those that experience only traditional lecture or virtual field trips (Tretinjak & Riggs, 2008). Elkins and Elkins (2007) showed peers learning the same material in a traditional lecture did not report these same gains and enthusiasms. Furthermore, Huntoon, Bluth, and Kennedy (2001) showed through a mixed methods study that a two-week long field course had an immediate and measurably positive impact in overall course competence and interest in geoscience for students enrolled in a lower-division non-majors course. Not only are field trips important for learning, they are listed as the paramount required course competency in many geology curriculum guidelines and outlines (Arizona Community College, 2010).

While field trips are important, they are also often challenging in a variety of ways. Many professionals record the difficulty in traveling to appropriate geologic terrains, while others note that it is difficult to prepare students adequately for field experiences (Calderone, et. al., 2003; Greenberg, 2002; Orion, 1993). It is highlighted in the literature that additional research is needed in determining which pedagogical strategies are most beneficial for developing better conceptual understanding in a field environment, so research in this arena is solicited by geoscience educators (King, 2008; Scott, Fuller, & Gaskin, 2006).

Theoretical Lens

Field trips are among the most academically and affectively valuable for students, are important for both majors and non-majors, and are considered to be integral parts of the curriculum at all levels (Beiersdorfer & Haynes, 1991; Kern & Carpenter, 1984; Knapp, 2007; McKenzie, 1986). Field trips are also experiential in nature, allowing students to have an authentic encounter with content, which will help students gain a deeper understanding of the material (Kolb, 1984). John Dewey, an influential philosopher, psychologist, and educational reformer, is the founder of ideas revolving around experiential learning (1938; 1944). He argued that people learn through hands-on experiences that need to be facilitated by a teacher, and that these experiences should be incorporated within educational systems (Dewey, 1944). David Kolb (1984), an educational theorist that drew heavily from Dewey, expanded on this concept, and described experiential learning as process-oriented, with direct and authentic

(rather than simulated) experience as necessary for bridging between concrete and abstract applications.

Constructivism is an epistemology that is not just about creating meaning, but is about constructing knowledge through interaction with stimuli (e. g., situations, problems) to which students are exposed (Gage & Berliner, 1998). King (2008) compared several geoscience studies that showed improvements in students' understanding of earth systems in classrooms utilizing constructivist approaches, whereas fewer gains were made when constructivist techniques were not employed. Orion (2007) concluded that focusing on the integration of problem solving approaches and inquiry learning, which are constructivist strategies, as well as utilizing the outdoors in order to produce an accurate model of earth systems, is critical for successful pedagogy in earth science. Additionally, the integration of activities throughout the learning process, not just a capstone project at the end of a curriculum cycle, is essential for success, particularly when conducting fieldwork in the natural environment (Orion & Ault, 2007). Orion and Ault (2007) further state that due to the complexities of the outdoor environment, there are aspects of authentic natural experiences that "cannot be cultivated indoors" (p. 761).

Local geologic features can be used to help students to effectively visualize larger, more complicated ones that may appear in a true field setting, and many urban and artificial environments have been used to teach complex geological concepts (Calderone et al., 2003; Francek, 1996; Kastens, Agrawal, & Liben, 2009). Inclusion of hands-on physical models during a lecture course has

also led to significant improvement in student conceptual change and achievement (Gray, Steer, McConnell, & Owens, 2010). Whereas active and kinesthetic feedback has been shown to be an important augmentation to science instruction as the curriculum is taught (Jones, Minogue, Tretter, Negishi, & Taylor, 2006), no studies have been done to consider the link between this initial local hands-on experience and a true field based one, in terms of content knowledge gains.

Factors Affecting Learning

There are many factors that have been identified in the literature that may affect a student's ability to process and interpret geologic phenomena while in an outdoor authentic field environment. Some of the factors are: spatial ability, self-efficacy, and novelty space, which are described in the following paragraphs.

Spatial ability. Visualization is defined as "a physical representation designed to make an abstract concept visible" (Reiner, 2008, p. 25). As students learn geology, they encounter much visualization from texts and other learning materials that try to convey scientific knowledge, but the students are also required to visualize geologic structures or processes directly from data and observations themselves (Kastens et al., 2009). The process of visualization has been linked as a skill referred to as spatial ability in the literature, which is defined as skill in "representing, transforming, generating, and recalling symbolic nonlinguistic information (Linn & Petersen, 1985, p. 1482). In the geosciences, spatial ability has been positively associated with success in the geosciences, with mental rotation being the aspect of spatial ability most linked with cognitive gains (Black, 2005; Lord & Rupert, 1995; Ormand, Manduca, Shipley, & Tikoff, 2010).

Mental rotation involves the ability to quickly and accurately rotate a two or three-dimensional object and is the skill most often linked with describing geologic phenomena in a field environment (Black, 2005; Linn & Petersen, 1985). Students in the geosciences may self-select for this ability, with non-science majors showing less ability than science majors, even with the same amount of previous experience and coursework (Nordvic & Amponsah, 1998; Ormand, et al., 2010). Some researchers have shown that males may outperform females on spatial ability pre-tests but females show more gains and end with the same post-test scores as males (Kali & Orion, 1996; Reynolds et al., 2005).

Black (2005) found a positive correlation between spatial ability and scores on a test of Earth science conceptual understanding for non-majors, regardless of gender, concluding, "results suggest that an opportunity may exist to improve Earth science conceptual understand by focusing on spatial abilities" (p. 402). Kali and Orion (1996) also state that spatial ability can be improved by providing students with opportunities to visually disassemble geologic layering and structures through concrete physical models or virtual simulations.

Self-efficacy. Bandura (1997) defines self-efficacy as a belief in "one's capabilities to organize and execute courses of action required to produce given attainments" (p. 8). Self-efficacy has been linked to performance expectations and outcomes, with more efficacious students performing better in geoscience courses (McConnell et al, 2010; van der Hoeven Kraft et al., 2010). Bandura (1986) identified four sources of self-efficacy: mastery experiences, modeling, social persuasion, and physiological factors. The first, and most important source

of efficacy, mastery experiences, is an experience that gives an individual

successful practice with a topic area or task (Bandura, 1997).   The second source,

modeling, occurs when individuals observe others successfully performing a task

they aspire to perform themselves (Bandura, 1997). Social persuasion occurs

when others encourage an individual to successfully complete a task, which

Bandura also warns can negatively influence efficacy with false praises or

inaccurate appraisals of an individual's ability (1994).   Physiological factors,

such as mood and reactions to stress can also affect an individual's self-efficacy

(Bandura, 1994).

Recently, the affective domain of college students at a variety of schools

enrolled in introductory geology courses has been measured through GARNET

(Geoscience Affective Research Network), an NSF funded project (DUE-

1022917) heading into Phase 2 of research. GARNET administered the

Motivated Strategies for Learning Questionnaire (MSLQ), created by Pintrich,

Smith, Garcia, and McKeachie (1993), which is an assessment instrument

designed to measure self-efficacy. The MSLQ was administered nationwide to

college students enrolled in introductory geology courses.   GARNET researchers

found that self-efficacy was the factor most correlated with individual academic

success, individual course grades, and geological concept test scores, during a

semester long course (Bykerk-Kaufman et al, 2010). The GARNET study also

reported that the self-efficacy of the entire student population showed a negative

shift from the beginning to the end of the semester, and that self-efficacy of the

females was significantly lowered with respect to the male counterparts, though

both males and females ended with similar course grades (Vislova et al, 2010).
Vislova et al. (2010) suggested that a student's perception of their final semester
grades might skew the self-reported efficacy results to be more negative at the end
of the semester, so this should not be measured at the end of a course.
Additionally, though females have an overall lower self-efficacy related to
geoscience coursework, they perform as well as their male counterparts in overall
course grades.

In a subset of the GARNET research population, self-efficacy was also
shown to correlate with performance, showing students with higher self-efficacy
and lower GPA or concept test scores earned the same grade as students with
lower self-efficacy and higher GPA or concept test scores (McConnell et al.,
2010). This correlation suggests that prior knowledge is not as strong a
determining factor of academic success, overall course grade, as self-efficacy.

Novelty space. Novelty space, or "the presence of new, unfamiliar, or
relatively rare stimuli against the background of familiar events in the child's
perceptual history" (Alberti & Witryol, 1994, p. 130), may also impact student
learning in a field environment. In some situations, the novelty of attending a
geologic field trip can increase motivation in students, but there is evidence to
suggest that the level of perceived novelty that students experience affects the
type of curiosity behaviors and ultimately the subsequent cognitive learning
outcomes (Falk & Bailing, 1982; Falk, Martin, & Bailing, 1978; Martin, Falk, &
Bailing, 1981). These studies stated that high levels of perceived novelty
negatively affected learning, particularly in the initial stages of a visit. Hurd

(1997) showed that "very high levels of perceived novelty result in high levels of exploration and setting information gathering, which take precedence over on-task, institutionally intended learning, and this is likely to result in low levels of learning" during trips to novel spaces (p. 118). Orion (1993) also noted this negative correlation and stated that although this aspect of novelty during a field experience may seem trivial, it relegated most field trips to "adventure-social events" (p. 365). Therefore, the novelty of a geologic field trip can trump any potential cognitive gains from an authentic field experience, and steps should be taken to mitigate novelty. Hurd (1997) and Orion and Ault (2007) suggest exposing students to information and stimuli prior to field strips can offset this negative affect. Because geologic field trips are outdoor experiences where complex geologic processes are analyzed and discussed, students should therefore be exposed to the outdoors, analytical procedures, and complex geology prior to a field trip.

Conclusion of Literature Review

Geology, the study of the earth, is a dynamic science. Within the field of geology, field trips play a pivotal role in engaging students and helping them to understand the science. Delivering field trips is fraught with difficulty, including: travel, budgetary constraints, and the basic delivery of information to students. This research study is focused on mitigating one of these factors by improving the transition of the students from the traditional laboratory environment to the authentic field environment. The literature previously reviewed helps inform the innovation proposed in this study in a variety of ways, including the design of the

intervention, as well as potential barriers to effectiveness. The literature suggests

that learning in field environments is accomplished through hands-on, experiential

learning, integrated throughout the curriculum. It also suggests that spatial

ability, self-efficacy, and novelty space can impact learning in a field

environment, and that gender can play a role in self-efficacy and spatial ability of

students. The innovation proposed in this study takes these parameters into

consideration from design, to methodology, and through data analysis and

interpretation.

Chapter 3

INNOVATION

An innovation was developed and implemented with the intent to scaffold

learning between the classroom and authentic geological environments by

utilizing a unique artificial geologic landscape called the GeoScene. The

GeoScene was utilized in this study as an intermediary between laboratory and

authentic field based experiences, allowing students to apply traditional laboratory

learning in an outdoor environment. The GeoScene represents a faux field

environment; outside, more complex and tangible than a laboratory, but also

simplified geologically and located safely within the confines of an educational

setting.   This chapter provides detailed information of how the GeoScene was

designed and constructed and how it was utilized in the classroom setting.

The Making of the GeoScene

The GeoScene was constructed with a new natural science building on the

ACC main campus, which was completed in May 2009. The natural science

building was built with monies from a 2006 bond election, and was one of four

new physical science buildings that have been built throughout ACCD in the last

five years. The GeoScene is a unique feature to the science building at Arizona

Community College, and was designed by me for educational purposes. The

architectural firm originally designed the geology courtyard and envisioned an

amphitheater with rocks bordering one wall. During this initial design phase, I

worked with the architect to select and arrange the rocks. The selected rocks

display classic, identifiable features, and were brought in from localities

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throughout the United States. The rocks were organized within the wall to show simplified geologic relationships to those seen in nature. The relationships exhibited on the GeoScene are intentionally simplified from those found in true field experiences, but they are more visual and contextualized than those presented in the laboratory. Additionally the GeoScene was designed to allow students to utilize hands-on techniques to a larger scale feature, more representative of interpreting geology in a field environment. The ultimate goal of this exploratory research was improving the transfer of laboratory concepts to an authentic field environment, but without negatively impacting gains in the traditional laboratory setting.

Implementation

Students enrolled in two separate laboratory sections of Historical Geology (GLG104) that shared a common lecture course were invited to participate in this study. The laboratory sections met independently, with one section on Monday and one on Wednesday. One section was designated as a control group and participated in traditional laboratory activities, whereas the other laboratory section was designated as the treatment group, and participated in a mixture of traditional and GeoScene activities. Figure 2 illustrates the implementation concept.

Figure 2

Implementation of GeoScene Innovation

Traditional laboratory activities for both the control and treatment group were conducted similarly throughout the entire semester. The focus of the intervention was on Laboratory sessions 3 through 6 (L3-L6), which will be described in greater detail. In keeping with the pedagogies established in the geosciences to maximize cognitive gains, L3-L6 were designed utilizing constructivist approaches (King, 2008). These approaches allow students to reconstruct their own meaning through experiences that access their prior knowledge and apply it to a new situation (Gage & Berliner, 1998). The labs were also designed to highlight experiential learning and aid in a successful transition to field environments. They therefore focused on inquiry and problem-solving activities, visualization, and included hands-on physical models or samples throughout the entire activity (see Laboratory 4 in Appendix B) (Gray, et al., 2010; Orion, 1997, Orion & Ault, 2007).

Each laboratory period (L3-L6) began with a brief introduction to the laboratory activities for the day. These were largely logistical explanations related to equipment (e.g. where samples or materials were located in the room or how to hold the compass). Students then began the lab, usually in small groups of their choosing, though they were allowed to work alone, and proceeded at their own pace until the lab was completed. During this time, they were free to move about the room, speak with other members of the class not in their groups, and ask me questions for clarification. The Internet was also available in the room at all times for students to openly access information or look up examples or materials, and they were encouraged to take advantage of that resource. These initial laboratory assignments represented the majority of the assigned material and were identical for both the control and treatment group. The laboratories were designed to build upon prior knowledge, engaging the students through inquiry-based exercises and build upon experiences through the interaction with stimuli (authentic materials) in the classroom.

The treatment group went on to complete a short application activity at the GeoScene. GeoScene activities were designed to follow the regularly scheduled laboratory exercises (L3-L6), to provide a short, hands-on application of the material covered during the lab. This application was self-paced for each student or group and was designed to last between 10 and 20 minutes for each of four designated labs, which represents approximately 10-15% additional lab time. The GeoScene activities were an additional application of concepts and skills previously taught in the lab, not the introduction of any new material (see the final

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pages of Lab 4 in Appendix B). This happened for four sequential weeks, directly

following completion of regular laboratory exercises. After individuals in the

treatment group completed this activity, they were free to leave for that week.

The control group also completed additional laboratory activities in the lab

room, which modeled the previous laboratory exercises. These activities took

approximately 10-20 minutes to complete and followed the pedagogical practices

employed throughout the regular lab time. Again, no new material was presented

during these laboratory exercises. Students were free to leave after they had

completed the additional activities.

These activities continued for four sequential weeks (L3-L6), and then

students participated in two consecutive field trips to analyze and interpret

geologic formations in an authentic field environment. In the field environment,

students were asked to identify rocks and minerals, determine geologic

relationships, and interpret geologic history, utilizing the information and skills

they had learned and built upon during L3-L6.

Researcher Role

This action research study took place within a classroom setting, my

classroom, so I was an integral part of the teaching and learning process.

Throughout the innovation, I moved about the room as an observer, but also

engaged with the students. This engagement involved discussion, while directly

responding to questions or active dialogue initiated by the student, but also during

times when I observed a student need assistance or clarification.   Sometimes

discussion was conducted with an individual and other times it was a group

dialogue. During the intervention phase of the laboratory, I moved between the indoor and GeoScene environment during the treatment labs, and was available uninterrupted for the control group. I modeled interpretive techniques, reinforcing or clarifying interpretations and instructions, and addressed misconceptions, just as I did during the regular laboratory time. In this way, I was an active part of the classroom and intervention.

Summary of Innovation

The study involved utilizing the GeoScene as a short additional hands-on application for students after concepts had been taught in a traditional laboratory environment. The application occurred weekly after four sequential labs, allowing students to have a short, approximately fifteen minute, application experience in the GeoScene environment. The GeoScene represented a hands-on, three-dimensional environment where students apply laboratory concepts to a larger, more complex geological feature that one that could be created or visualized in lab. This feature is located outside the classroom, but within the confines of the school, so it provided an outdoor application experience for students to aid in the transition to an authentic geological environment.

Chapter 4

METHODS

Utilizing the innovation previously described, an action research study was designed and implemented to systematically analyze the influence the GeoScene may have had in helping students to apply laboratory concepts in an authentic field environment. The following chapter describes the research methods employed to addressed these research questions:

1. Does replacing classroom-situated laboratory exercises with GeoScene applications affect student comprehension and interpretation of geologic phenomena in the laboratory environment?

2. Do GeoScene applications affect student comprehension and interpretation of geologic phenomena in an authentic field environment? If so, how and why?

The research approach and methods are designed to explore these questions by establishing a dynamic approach and providing multiple qualitative and quantitative data sources to lend more robust results through triangulation. First, action research and mixed methods are defined. Then the research setting participants are described in greater detail. Next, the data collection tools and techniques utilized to thoroughly address the research questions are explained. Lastly, analysis of the data resulting from the collection tools is described.

Action Research Mixed-Methods Approach

The study utilized an action research methodology. Mills (2007) defines action research as a "systematic inquiry conducted by teacher researchers,

principals, school counselors, or other stakeholders in the teaching/learning

environment to gather information about how their particular schools operate,

how they teach, and how well their students learn" (p. 5).

I was an active part of this study, as the instructor and researcher, and I

gathered information about how I taught and how my students learned. In most

pedagogies based on constructivism and experiential learning, the teacher's role is

not only to observe and assess but also to engage with the students while they are

completing activities, wondering aloud and posing questions to the students for

the promotion of reasoning (DeVries, Zan, Hildebrandt, Edmiaston, & Sales,

2002). These constructivist pedagogies involve the teacher as participant, and this

participation is also an essential feature of action research (DeVries et al, 2002).

Stringer (2007) further states that action research is local in context and

may not be generalized to a larger population due to the context of the situation.

This local context is particularly appropriate, because it utilized a physical feature

located at Arizona Community College, and tested only in a local environment.

While it is possible that other artificial outcrops could be replicated and studied in

other places, studying other artificial outcrops was beyond the scope of this action

research project. The focus is on teaching and learning in this setting, there is

hope that this research could lend insight into lessons that can be utilized within

laboratory classrooms in other educational settings that hope to scaffold student

learning into an authentic field environments.

This study utilized a mixed methods research design. A mixed methods

research design, utilizing both quantitative and qualitative methods, is appropriate

for action research, because it allows for multiple ways to understand phenomena (Gay, Mills, & Airasian, 2009). Mixed methods design involves a blending of data collection techniques in order to enhance understanding of complex research questions (Green, Caracelli, & Graham, 1989). Threats to internal validity can be controlled, results can be enhanced or expanded, and new research questions can be initiated through the blending of methods in mixed methods research design (Green et al., 1989).

Setting and Participants

Arizona Community College is a two-year college that focuses on technical job training and transfer degrees to four-year universities (Van Zile, 2008). Though located on a Native American reservation, with open enrollment to the entire surrounding community, ACC is predominantly composed of traditional college-aged (18-25) white students with little to no previous college experience (Cohen & Hughes, 2009). Because the introductory geology classes are general education courses, conducted during the day, they are composed of students demographically similar to the overall campus population. Geology is not required coursework for any other physical or life science degree (Aztransfer.com, 2010), so the students in geology classes are typically non-science majors.

Because all of the activities fit within the domain of normal course content, all activities were required and a part of the overall grade. However, students had the opportunity to opt out of research component (see consent form Appendix A). The consent form was collected by a colleague not involved with

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this research, and kept confidential until after all data is collected and course grades were finalized at the end of the semester.

Data Sources

For this action research study, the following data sources were used: a pre/post laboratory test, video recordings, student reports, teacher analytic memos, two field practical examinations, and semi-structured student interviews. These were used to determine whether the GeoScene was an acceptable alternative to similar laboratory instruction and gain a more complete understanding of how applying laboratory concepts at the GeoScene affected student learning. The methods will be explained and defined in the procedures and data collection section.

Data Collection

The study was conducted over ten weeks of the 13-week laboratory course, beginning with data collection during the second week. It was necessary to wait until the second week to begin the study, since the college has an open enrollment period during the first week of class, and laboratory class enrollment does not stabilize until after the first week. Data collection officially ended two weeks prior to the end of the semester, so that data could be analyzed while the students were still in session. The instruments are shown in Table 1, and will be discussed in the order of their application within the course.

Table 1

Timeline of Research Instrument Application

Lab Period	Control	Treatment
Lab 1 (L1)		
Lab 2 (L2)	Pre-test / Memo (M)	Pre-test / Memo (M)
Lab 3 (L3)	M /Student Reflections (SR)/ Video Recording (VR)	M/ SR/ VR
Lab 4 (L4)	M / VR / SR	M / VR / SR
Lab 5 (L5)	M / VR / SR	M / VR / SR
Lab 6 (L6)	M / VR / SR	M / VR / SR
Lab 7 (L7)	Post test /M	Post test /M
Lab 8 (L8)	Field Trip Exam 1 /M/SR	Field Practical Exam 1 /M/SR
Lab 9 (L9)	Field Trip Exam 2 /M/SR	Field Trip Exam 2 /M/SR
Lab 10 (L10)	Semi-structured interviews	Semi-structured interviews
Lab 11 (L11)	Semi-structured interviews	Semi-structured interviews
Lab 12 (L12)	No data collected	No data collected
Lab 13 (L13)	No data collected	No data collected

Pre/post test. This instrument was administered at the beginning of the second lab period and took approximately 30-45 minutes for students to complete. It was broken into two parts, which were administered sequentially (see the entire survey in Appendix C). Part 1 was designed to measure geologic concept understanding related to L3-L6, spatial skills, self-efficacy, and overall exposure

to outdoor experiences. Part 2 was designed to capture demographic information, prior coursework taken in geology, and student major.

This test was piloted in the spring of 2011, with the exception of the geologic concept-understanding portion. A Cronbach-alpha analysis was conducted on the pilot to determine reliability of the survey, with the constructs of self-efficacy and novelty yielding a high degree of reliability (self-efficacy $\alpha=.863$, novelty space $\alpha=.887$) (Cronbach, 1951). Mental rotation yielded a lower degree of reliability ($\alpha=.582$), and the geologic concept test was not previously piloted. The mental rotation inventory came from the Purdue Visualizations of Rotations Test, which has shown a high degree of reliability in independent testing ($\alpha=.875$) (Bodner & Guay, 1997). The low Cronbach-alpha for mental rotation on the pilot may have been due to the small number of students involved ($N=5$) or due to clarity of instructions. Students involved in the pilot expressed confusion on how to record their answers, and so this process was simplified for the innovation study.

The questions for the pre-test were selected from two published sources and two inventories created for this intervention. The published sources were: the mental rotations portion of the Purdue Visualization of Rotation Test (PVRT) and the self-efficacy construct of the Motivated Strategies for Learning Questionnaire (MSLQ). The test also contained several questions to assess a students experience and comfort with the outdoors, which the researcher developed and piloted, as explained previously. Additionally, there were questions that were constructed to track ability in the geologic concepts directly related to the laboratory exercises

(L3-L6), shown in Appendix C. The content questions were class tested over several semesters in the same geology course at another nearby community college, as well as validated by geology professors not directly related with the study.

Utilizing the information on the pre-test, comparisons between groups pertaining to spatial ability, geologic concept ability, self-efficacy, and outdoor exposure were established at the beginning of the semester. The post-test consisted of only Part 1 of the pre-test, and was administered prior to the field examinations, during Lab 7 (Table 1). Analyzing the pre/post test results allowed for tracking and comparing of gains of the students in the control and treatment groups. This directly addressed the first research questions to determine if the GeoScene applications were an appropriate substitute for laboratory work.

Purdue visualizations of rotations test (PVRT). A ten-question subset of the PVRT was utilized to measure spatial ability, specifically mental rotation. The PVRT consists of questions designed to measure a subject's spatial ability regardless of content (Bodner & Guay, 1997). To restrict analytical processing that may skew the results, a time limit of three minutes for the 10-item version of this test is strictly enforced, in accordance with instrument development.   The PVRT is considered reliable by analyzing Kuder–Richardson reliability coefficients ($r = 0.61$, $p < 0.001$) (Bodner & Guay, 1997). The authors also showed that the PVRT is among the spatial tests least likely to be confounded by analytic processing strategies.

Motivated students learning questionnaire (MSLQ). In order to determine self-efficacy, a subscale of the MSLQ was utilized. The MSLQ is a self-reported instrument designed to measure students' motivation and use of learning strategies (Pintrich, et al., 1993). It is constructed with fifteen subscales, with the self-efficacy scale showing statistically significant reliability ($\alpha = .93$, $p < .05$) and promising predictive validity for self-efficacy with overall course grade ($r = .41$) (Pintrich et al., 1993). The MSLQ self-efficacy subscale also contains questions related to a student's expectancy of success, which is not included in Bandura's definition of self-efficacy (Bandura, 1993). However, Pintrich defines self-efficacy using the same definition as Bandura (Pintrich, 2000), so Bandura's techniques to increase self-efficacy should be captured by the MSLQ self-efficacy subscale regardless of the inclusion of expectancy. The MSLQ self-efficacy subscale consists of nine questions, which measure self-efficacy on a 5-point Likert scale (Appendix C).

Novelty space. Additionally, there were questions on the pre/post survey to assess how much experience and comfort a student has with the outdoors. This portion consists of five Likert-scale questions. This data help to determine if students felt comfortable outside and if the GeoScene affected that overall comfort over time. This addressed the concern of novelty space, which can affect student learning in a field environment, as previously outlined in the literature review section.

Geologic concept ability. The questions used to assess geologic concept ability were taken from quiz materials class tested at a nearby community college. These questions were developed to assess similar skills in the same class

researched for this study, with a focus on those concepts specifically taught in L3-L6. Since this part of the assessment was not piloted, additional experts in the field of teaching historical geology were asked whether the instrument assessed the competencies taught in historical geology. All three experts asked confirmed that the assessment tool, while not perfect, was an acceptable tool.

Memos. Glaser (1978) defines a memo as the "theorizing write-up of ideas about codes and coding as they strike the analyst…a sentence, a paragraph…it exhausts the analyst's momentary ideation based on data with perhaps a little conceptual elaboration" (p. 83-84). While in the laboratory and GeoScene setting, I was constantly engaging with students, which does not allow for extensive note-taking or journaling. Memoing allowed me to record interesting interactions, themes, or side-conversations that occurred throughout the classroom, as an "analyst on the fly," since they are a rapid way to record thoughts that occur throughout data collection and analysis (Miles & Huberman, 1994, p. 75). These memos were an essential data collection point, as they were a record of what was happening in the laboratory environment. They also helped to specifically address the research questions by addressing the impact the GeoScene had on learning. Miles and Huberman (1994) state that "memoing" allows the researcher to "confront" the initial research frameworks and identify places where it may need to be revised, and may also allow for insight for further data collection, like interviews (p. 74). These memos were recorded as they occurred during L2-L8 for both the control and treatment groups, as this covered the course of the intervention. They were recorded in a notebook as field notes during the

laboratory session and transcribed and expanded immediately after the session in which they occurred.

Student reflections. Student reflections were built into each of the L3-L8 laboratories (Appendices B and D). The reflections prompted the student to assess their own understanding and articulate any problems they may have encountered with the content, which served as both a source of metacognition for the student and a record of their understanding for the researcher. Metacognition "involves the capacity to monitor, evaluate, and know what to do to improve performance" (Schunk, 2004, p. 19). Sources of metacognition include: checking understanding, predicting outcomes, accessing prior learning, and switching to different learning activities (Schunk, 2004). This data source specifically targeted what learning was occurring in the laboratory and field environment, which directly addressed the research questions. The student reflections were transcribed directly from L3-L8 for each student.

Visual recording of innovation. Interactions during the four GeoScene laboratory applications for the treatment group and the four corresponding exercises for the control group were recorded visually, utilizing a digital video camera. One stationary camera was set up at the GeoScene outcrop in order to record the treatment group activities. One stationary camera was set up in the laboratory classroom for the control group in order to record their additional laboratory activities. Due to the size of the area, audio recordings were captured only the limited area around the stationary camera. In order to aid in recognizing

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when students were completing the additional control group activities, the corresponding laboratory pages were copied on colored paper.

The images and audio captured was used to determine how much time individuals and groups spent on the additional laboratory activities. Kastens, Agrawal, and Liben have shown that experts gesture about geologic processes more than novices, and that this gesturing is evidence of a higher level of concept and spatial understanding (2008, 2009). Therefore, the recording was coded for concept related gesturing, or geogesturing, of the students during the their time spent on the extra laboratory activities. As the student progressed through the activities, the recording helped to determine if geogesturing occurred and whether it changed throughout the intervention. Additionally, the recordings captured the number of times a student physically touched the GeoScene or other laboratory tools, as well as communication between lab participants. No video was captured during other portions of the course.

Field practical examinations. There were two successive field practical examinations conducted just after L6 (Appendix D). These examinations were a post only assessment conducted in the field to determine if students were successful analyzing geology in a field environment, which addressed the second research question. Both field examinations assessed the student's abilities in the four topic and ability areas covered in laboratory sessions three through six (L3-L6). Both had a ten question 5-point Likert scale self-efficacy survey that was administered prior to the field trip (see page 1 of each field practical exam in Appendix D). The field practical examinations consisted of open-ended, content

related questions, related to the topics covered in L3-L6. These content questions were scored using the rubrics in Appendix E.

Semi-structured student interviews. After all of the previous data sources were collected and initially analyzed, semi-structured interviews were used to check and to expand on findings, as well as evaluate constructed themes (Miles & Huberman, 2009). Specifically, a purposeful sample of key informants was selected as a focus population of all students involved in the treatment group (Stringer, 2007). These "information-rich" study participants were selected through an analysis of student reflections, researcher memos, previous coursework, gender, performance data on the pre/post test and field practical examinations, as well as interaction with the GeoScene (Wiersma, 1995, p. 298). The semi-structured interviews were used to gain understanding of all the research questions, and support theme construction that potentially cross over many data sets. These interviews were conducted during L10 and L11 (Table 1) using the Interview Protocol in Appendix F, and were audio recorded and transcribed for analysis.

Data Analysis

The instruments previously described produced several types of data to address the research questions. The instruments provided both qualitative and quantitative data sources, which were analyzed with the techniques described in the following paragraphs. This study addressed the following research questions:

1. Does replacing classroom-situated laboratory exercises with GeoScene applications affect student comprehension and interpretation of geologic phenomena in the laboratory environment?

2. Do GeoScene applications affect student comprehension and interpretation of geologic phenomena in an authentic field environment? If so, how and why?

Qualitative data analysis. Qualitative data, including: student reflections and interviews were analyzed to determine emerging themes using the constant comparative method (Glaser & Strauss, 1967). In this procedure, open and axial coding was used to initially identify concepts and then develop subsequent categories that represent phenomena related to the data. Open coding is the initial phase of qualitative data analysis, where first level observations and text is labeled in a way to indicate patterns and meanings, while axial coding is a second level coding process that establishes themes among the data (Glaser & Straus, 1967). The open coding themes were constructed by a line-by-line analysis of the data. The researcher completed all transcriptions, which accounted for approximately 40 hours of initial analysis, so an intimate understanding of the text was present at the time coding analysis began.

The researcher memos were essentially axially coded into patterns as they were written. These memos were written as explanations, drawing together themes between bits of data and supporting those themes with evidentiary warrants (Miles & Huberman, 1994). Since these memos were already

interpretations of phenomena, supported by observation, they were sorted by similar themes to determine if any of the patterns were pervasive.

The visual recordings were systematically analyzed. Each of the eight hour-long recordings was watched without interruption. Then the recordings were cut into segments for each individual or group of students, approximately 15 minutes in length, which allowed time on task to be calculated. Each student segment was then watched and coded for the behaviors of the students, describing: interaction with the GeoScene/laboratory materials and geogesturing, as well as observations of individual student actions. This was a thorough process, which broke each video segment into five-second frames to be observed and annotated. Due to the stationary nature of the camera, not all student activities could be discerned. This process represented approximately 47 hours of analysis. A second reading of the intervention recording annotations was then conducted where new codes were identified and analyzed using the open and axial coding described previously.

Quantitative data analysis. The quantitative data analysis drew from the pre/post test, student reflections, and the two field practical examinations using SPSS, a statistical software package. SPSS allowed data displays of frequencies, descriptive statistics, and relationships between and among data. A Cliff's Delta Calculator was used to calculate effect sizes (Macbeth, Razumiejczyk, & Ledesma, 2011).

The pre/post test was graded utilizing a correct/incorrect outcome designation for the spatial skills and the content knowledge portions. The control

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and treatment tests were mixed together and graded anonymously. The field tests were also mixed together and graded anonymously utilizing the rubric in Appendix C. The grading occurred after both field tests were collected, and the scores from the field tests were aggregated, because the same content was not covered equally in each test, nor were they worth the same number of overall points.

Using a Mann-Whitney U-test, the constructs on the pre/post survey (spatial ability, content knowledge, self-efficacy, and novelty space) were measured between control and treatment groups to determine if the groups were similar. Due to the small sample size involved in the study, nonparametric data analysis was utilized to produce more conservative estimates. The Mann-Whitney U-test is used to compare independent groups when normality and homogeneity of data cannot be assumed, particularly due to a small number of samples (Mann & Whitney, 1947). The data captured were treated as ordinal numbers, meaning that the numbers were used to rank individuals, rather than assuming an inherent consistent value between numbers. This analysis was also conducted with the field practical examinations.

To determine the power of the Mann-Whitney U-test statistic, an effect size calculation was conducted in order to further support the statistical findings by reporting the strength of the relationship (e.g. the change from the pre/post test for the control and treatment groups) (Cohen, 1988). Due to the nonparametric data captured in this study, a Cliff's delta was calculated rather than a Cohen's *d*. Cliff's delta does not assume normality or homogeneity of data, and therefore

yields a more reliable effect size calculation for this data set (Hess & Kromrey,

2004).   Cliff's delta represents the degree of overlap between the two

distributions of scores. It ranges from −1 (if all observations in group 1 are larger

than all observations in group 2) to +1 (if all observations in group 1 are smaller

than all observations in group 2) and takes the value of zero if the two

distributions are identical (Hess & Kromrey, 2004). The internal reliability of the

pre/post survey and field practical examinations was measured using Chronbach's

Alpha test (Cronbach, 1951), just as conducted during the pilot survey.

A chi-squared analysis of the pre in-class survey for the control and

treatment groups was conducted in SPSS in order to help to determine if there

were any major demographic differences between the groups, since the groups are

nonequivalent (Smith & Glass, 1987; Gay, Mills, & Airisan, 2009).

Validity

The strength of mixed methods research lies in the process of collecting

multiple data sets in many ways to come to some sense of understanding about

phenomena, in this case, the effects of the GeoScene on learning in a field

environment. To increase validity, the data were triangulated across multiple data

sources to determine consistent interpretations (Denzin, 1978; Campbell & Fiske,

1959; Miles & Huberman, 1994). Triangulation is a commonly used term in

mixed methods research to describe the process of utilizing multiple data sources

in order to describe a phenomenon, involving the process of cutting across two or

more methodological techniques to cross-check similar themes among and in

between different data sets to capture a more complete, and valid picture of what is being studied (Gay, Mills, & Airasian, 2009).

There are threats to validity in any study, in general, and this study, in particular, both internal and external. These validity issues will be discussed, as well as any attempts to mitigate the source. Internal validity refers to the extent to which one can claim that the independent variable (the GeoScene) is responsible for the dependent variable (increased understanding and content application in a field environment) (Smith & Glass, 1987). The control and treatment groups are considered nonequivalent, because the students involved in the study were not a random sample, which is a threat to internal validity (Smith & Glass, 1987). In an effort to mitigate this, demographic data, prior knowledge, and the pre-survey was collected to help to determine the equivalence of the control and treatment groups.

A major limiting factor that affected validity in this study was the small sample size for quantitative data analysis and interpretation. Even though there was a 100% intervention completion rate of the students involved in the study, the research questions were primarily addressed with qualitative data sources, with the quantitative data collection supporting an exploration of the phenomena where possible. This allowed for the quantitative data to aid in the triangulation of sources, rather than standing independently.

Threats to external validity compromise the generalizability of a research population the to general population (Smith & Glass, 1987). Though generalizability is not the focus of action research in common, and this study in particular, there are still some threats that need to be addressed. The Hawthorne

effect refers to the specific threat that could be caused because the students know they are part of a study (Smith & Glass). The control group could do worse, simply because they understand they are not getting a helpful treatment, conversely, the treatment could do better specifically because they think they should. The Hawthorne effect may result in a difference between the control and treatment groups that had nothing to do with the treatment. To help mitigate this threat, the groups were not referred to as a control/treatment group. Students were not allowed to switch labs during the semester, so they were not explicitly aware of the difference in the laboratory sessions. The students knew they were a part of the study, and signed a consent form, but they did not know what the study was about. Nothing could guarantee that the students did not speak about the differences between their individual laboratory sections during the common lecture course, so this effect could not be fully negated, however the students would have not been aware what the differences between the sections meant.

Additionally, the experimenter effect could be a threat to external validity. The experimenter effect recognizes my role in the research, personal charm and energy, as well as the fact that I knew what the study was about and could collect data to inform my preconceived conclusions (Smith & Glass, 1987). This was a difficult effect to mitigate, because I was the only researcher involved in the study. The visual recording information was utilized to confirm similar researcher behavior between groups, as well as memos that were written after each session. During the field practical examinations, the dialogue of the

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instructor was scripted for consistency. Even with these precautions, this threat to validity cannot be fully negated.

Conclusion of Methods

This research was an exploratory mixed-methods action research study, designed to blend qualitative and quantitative data sources to triangulate reliable conclusions and interpretations. It was a systematic approach to gain insight into the learning that occurred with introductory geology students as they transitioned from a traditional laboratory setting to an authentic field based environment utilizing a intermediary artificial geologic outcrop.

Chapter 5

RESULTS AND DATA ANALYSIS

The following chapter is broken up into three discrete sections. The first section compares the control and treatment participants utilizing their demographic information and performance on the pre-test. This was done to determine if there were any apparent differences in the control and treatment populations prior to the intervention. The pre/post test was also validated for reliability.

The next section addresses the first research question: Does replacing classroom-situated laboratory exercises with GeoScene applications affect student comprehension and interpretation of geologic phenomena in the laboratory environment? This research question was addressed by analysis of the post-test results, student reflections, interviews, and video recordings.

The final section addresses the second research question: Do GeoScene applications affect student comprehension and interpretation of geologic phenomena in an authentic field environment? If so, how and why? This question was addressed by analysis of the interviews, video recordings, student reflections, field practical examinations, and memos.

Comparison of Participants

There were several measures that were used to attempt to determine the equivalency of the control and treatment participants as research subjects. The participants were not randomly sampled from the student body at ACC, but rather they self-selected by enrolling in Historical Geology and determining which

laboratory section worked best for them. Neither laboratory section filled, so there were spots available for students to choose either section.   Specific demographic and cognitive features were measured at the beginning of the semester to determine if there were any measurable differences between control and treatment participants.

The control and treatment groups were compared utilizing basic demographic information, namely: gender, age, previous courses, race, major, and GPA. A Pearson's chi-square of independence test was conducted on the gender data, and resulted in no statistical difference between control and treatment ($p=0.320$). A Mann-Whitney U-test was used to compare student age, GPA, and previous coursework completed, and also yielded no statistical differences ($p=0.891$, 0.327, and 0.542, respectively). Analysis of self-reported race revealed that 10 of 12 students in the control group and 10 of 13 in the treatment, identified as white. This percentage is higher than the student demographic data reported by the college for the Fall 2011 semester (67%), but it is consistent between the two classes studied (Cohen & Hughes, 2012). There was only one student in each group that listed a science major. The demographic data collected and analyzed suggest that there were no measurable differences in age, race, gender, GPA, major and previous coursework completed between the control and treatment group participants at the time of the study. However, due to the small sample size, statistical comparisons cannot be viewed as negating the potential for differences in any of the demographic attributes of the students involved in the study.

The pre-test was utilized to determine the incoming self-efficacy, spatial skills, novelty space, and geologic concept knowledge of incoming students in the control and treatment groups. Table 2 shows a reliability analyses on each of the constructs within the survey instrument was conducted to determine the Cronbach-alpha coefficient (Cronbach, 1971). Cronbach's alpha determines the internal consistency or average correlation of items in a survey instrument to gauge its reliability (Cronbach, 1971). The results are shown for each construct, as well as the instrument as a whole, in order to compare the internal consistency across the entire instrument.

Table 2

Pre/Post Survey Instrument Coefficient-Alpha Estimates of Internal-Consistency Reliability.

Factor	Item #	Pre-Test		Post-Test	
		Control	Treatment	Control	Treatment
Mental Rotation (Spatial Skills)[a]	1-10	.61	.47	.54	.62
Content Knowledge[b]	11-35	.52	.59	.74	.76
Self-Efficacy[c]	36-45	.90	.85	.90	.94
Novelty Space[c]	46-50	.75	.75	.81	.87
Whole Instrument	1-50	.83	.88	.76	.84
Results Combined	1-50	.85		.84	

Note. N=25, Control n=13, Treatment n=12.
[a]These items were multiple choice with four potential answers.
[b]These items were open ended fill in the blank questions.
[c]These items were 5-point Likert scale questions.

Table 2 shows the instrument as a whole yielded a high degree of reliability (α= 0.85, 0.84) on the pre and post-tests respectively, however, some of the individual constructs yielded lower Cronbach-alpha scores (Cronbach, 1951). The construct of mental rotation shows a lower degree of reliability. The mental rotation inventory came from the Purdue Visualizations of Rotations Test (PVRT), which yielded a high degree of construct validity for mental rotation in independent testing, α= 0.875 (Bodner & Guay, 1997). In this study, however, Cronbach-alpha scores ranged from 0.47 (unacceptable) to 0.62 (questionable). The participants involved in this study were given three minutes to complete ten mental rotation questions. They had an average completion of five of these questions. Recalculating the reliability of the PVRT using only the first five questions of the survey increased its reliability in the pre-test (α=0.74 for the control, α=0.64 for the treatment) and the post-test (α=0.66 for the control and α=0.78 for the treatment). Though the reliability of the PRVT was robustly tested outside of this study and deemed reliable, it yielded an acceptable to questionable level of reliability even when accounting for the time limit errors.   For this reason, it was not utilized to compare general incoming traits of the participants or draw conclusions regarding a change in their abilities throughout the intervention.

The Content Knowledge construct also yielded lower reliability on the pre-test, but improved on the post-test. The content knowledge questions were open-ended rather than multiple choice, and a high number of questions were left blank on the pre-test (38%) versus the post-test (0.08%), which may have impacted the reliability calculation.

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The pre-test given during the initial laboratory for the control and treatment groups attempted to test the student's individual geologic content knowledge, self-efficacy, and novelty space concept. Table 3 reveals the results from the Mann-Whitney U-test conducted on results from the pre-test, which can be used to determine whether the statistical medians of control and treatment groups were comparable at the beginning of the intervention.

Table 3

Comparison of Control/Treatment Group Performance on Pre-test.

Factor	Mean Difference	Median Difference	SD Difference	p value
Self-Efficacy[b]	-1.23	-1	1.91	0.55
Novelty Space[b]	-1.50	-1	1.15	0.36
Content Knowledge[c]	-0.67	-1	1.13	0.55
Construct L3	1.01	1	1.07	0.47
Construct L4	-0.57	-1	1.24	0.23
Construct L5	-0.85	-1	1.09	0.36
Construct L6	0.21	0	1.26	0.76

Note. N=25, Control n=13, Treatment n=12. Treatment scores were subtracted from Control scores, yielding a negative number when the treatment group scored higher. A score of -1 means the treatment group scored 1 question higher, a score of 0 means the scores were even, a score of 1 means the control group scored one question higher. Raw data available by contacting author.

[a] These items were multiple choice with four potential answers.

[b] These items were open ended fill in the blank questions.

[c] These items were 5-point Likert scale questions.

The Geologic Content test was broken further into content relevant to the laboratory exercises addressed during the innovation (L3-L6). None of the factors

compared between the control and treatment group at the beginning of the semester yielded any apparent statistically significant difference between the control and treatment groups at the p≤ 0.05 level.

Interpretation of Comparison of Participants. Although neither participant group were randomly sampled, the aforementioned data suggest the control and treatment participants were similar in terms of gender, race, GPA, age, previous geology coursework, self-efficacy, novelty space, and geologic concept knowledge at the beginning of the semester, prior to the intervention. Although the study was conducted under the assumption of equivalence of participants, it is critical to note that it is possible that participant nonequivalence by regression interaction may have compromised the internal validity of the study, and the small number of participants compromises the statistical power of any claim (Smith & Glass, 1987). For this reason, multiple qualitative data sources were collected throughout the intervention to address the research questions and quantitative data were utilized to support and explore conclusions through triangulation.

Results and Analysis Related to Research Question 1

The first research question focused on whether replacing traditional laboratory exercises with GeoScene applications caused students to perform differently in the regular laboratory environment: Does replacing classroom-situated laboratory exercises with GeoScene applications affect student comprehension and interpretation of geologic phenomena in the laboratory

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environment? The student reflections, interviews, video recordings, and laboratory post-test were analyzed to examine this question.

Student reflections. Throughout the laboratory exercises, all students completed reflections related to their overall understanding of material. One measure of student comprehension was collected as students ranked their confidence in understanding the laboratory content within their reflections at the end of each lab (L3-L6), using a 1-10 scale. The students were asked to assess their understanding, with 10 being perfect understanding and 0 indicating no understanding of the material, and then asked to justify the ranking. The self reported understanding indicated that students in both the control and treatment groups ranked their understanding similarly (p=0.27). Additionally, student responses were coded using the open and axial coding process previously described and the results show students in both the control (75%) and treatment (85%) overwhelmingly reported that more practice or examples of laboratory materials would be the single most important component necessary to improve their understanding of the laboratory concepts. This indicates that students felt they understood the material similarly between the control and treatment groups during the intervention, and also that they identified the same sources to improve their understanding.

Interviews. Interviews were conducted with 7 of the 13 treatment students during the semester, after the intervention and field practical exams, utilizing the interview protocol in Appendix F. All seven of the treatment students interviewed stated that the GeoScene helped them understand in-class

laboratory content. One student highlighted the value of the GeoScene on their laboratory understanding by stating: "Yeah, I think after seeing it, I came back and changed things. I was like, ok, it made more sense after seeing it. Because it was more like…ok, I learned this stuff…and I get it…and then you see it. Now going back you now have a visual image on a bigger scale that you can relate to." Another student showed how the GeoScene enhanced their understanding of a specific topic by remarking:

> "Yeah, because you just practice it one more time. You go outside and practice it. Especially because…I think the first time that I was really frustrated with the GeoScene I was like wait, there's like five different colors of sandstone here…but I didn't figure that out in the beginning [of the lab]. So I was like, ok, this must be limestone, and this must be…but no, it's totally not, it's just all different…so that makes you realize that it [sandstone] comes in different colors obviously. So it's just like more realistic by going out there and seeing it like that."

A third student illustrated how the link to the laboratory was obvious by stating, "Yeah…with the strike and dip…the strikes and dips on [the GeoScene]…I guess, and distinguishing the rocks and lots of layering that we did and everything."

Overall, the students interviewed revealed favorable impressions of the GeoScene and its relationship to understanding laboratory material that they had encountered for the first time indoors. All students interviewed felt that it had enhanced the laboratory experience and aided in their understanding of the material.

Video recordings. The video recordings were utilized to determine time

on task for students for both the control and treatment groups during the

intervention activities. Table 4 shows the median time on task for students in

both the control and treatment groups, as well as overall time spent on the

innovation activities. Utilizing the median score, students in both the control and

treatment groups spent between ten and seventeen minutes on additional

laboratory activities. The time on task was measured in order to determine that

neither group got an unfair benefit of having more geology related activities prior

to engaging in the authentic field environment, which could have impacted their

understanding and comprehension in a field setting. There were no significant

differences calculated for the time spent on activities during any individual lab,

but the control group spent more time over the course of the innovation.

Table 4

Comparison of Control/Treatment Group for Time on Task During Innovation.

Activity	C (Mn)	C (Md)	C (SD)	T(Mn)	T (Md)	T (SD)	p-value
L3	14:22	12:14	00:29	16:15	15:15	00:55	0.09
L4	14:39	11:58	00:44	13:24	09:54	00:57	0.35
L5	15:19	14:37	00:16	12:18	12:30	00:34	0.12
L6	14:04	17:36	00:17	13:13	12:39	00:53	0.08
Total	58:01	55:55	00:31	55:12	55:37	00:46	0.41

Note. N=25, Control n=13, Treatment n=12. Mn=Mean, Md=Median SD=Standard Deviation
Numbers reported are in minutes:seconds.   Raw data available by contacting author.

Post-test. A Mann-Whitney U-test was conducted on the post-test, which

occurred after the innovation and was designed as a laboratory competency exam,

as well as intended to track changes in spatial ability, self-efficacy, and novelty

space concept. As reported previously, the spatial skills test was determined not

reliable enough to determine changes, so those data were omitted. Table 5 reveals

the results of performance on the laboratory post-test and shows that there were

no apparent significant differences between control and treatment groups related

to any individual laboratory content, overall content knowledge, or their overall

perception of self-efficacy or novelty space after the intervention.

Table 5

Comparison of Control/Treatment Group Performance on Post-test.

Factor	Mean Score Difference	Median Score Difference	Standard Deviation Difference	p value
Self-Efficacy[c]	-3.08	-3	-0.36	0.06
Novelty Space[c]	-1.5	-2	0.33	0.34
All Content[b]	-0.67	-1.5	-0.28	0.27
Construct L3	-0.81	-2	-0.47	0.325
Construct L4	0.04	0.5	0.05	0.955
Construct L5	-0.12	-1	0.44	0.108
Construct L6	0.61	0	0.02	0.868

Note. N=25, Control n=13, Treatment n=12. Treatment group scores were subtracted from control group scores. Positive numbers indicate the control group scored higher, negative numbers indicates the treatment group scored higher.   Raw data available by contacting author.

[a] These items were multiple choice with four potential answers.

[b] These items were open ended fill in the blank questions.

[c] These items were 5-point Likert scale questions.

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Interpretations of data for research question 1. The treatment students spent less time working on activities in the traditional laboratory setting, which could have impacted their comprehension and understanding of geologic activities learned in the lab. No two groups of students are alike and professors eagerly provide a multitude of vignettes illustrating the drastic differences in abilities from class to class and semester to semester. For this reason, student performance in the laboratory setting was triangulated utilizing multiple data sources, including: student reflections, interviews, video recordings, and a pre/post laboratory test. By utilizing the results from these data sources, an inference can be made that treatment students were equally prepared for the laboratory assessments and environment, even though they spent a shorter amount of time in that lab environment.

Students reported similar confidence in the laboratory content, and stated the same weaknesses in their reflections. They gave specific examples of how and where the GeoScene benefitted them solely in the laboratory setting. They also spent approximately the same amount of time on task, and they performed comparably on the laboratory post-test. Therefore, the interpretation that the GeoScene was a reasonable substitution for laboratory environments is supported. The treatment students did not experience any academic harm related to that exposure, and while there was not a significant difference in the post-test performance, on average, students in the treatment group scored higher and spent less time on the extra activities.

Utilizing all of the data sources together, it is therefore reasonable to assume that no harm was done to the students involved in the treatment by shortening the amount of time they spent on traditional laboratory activities, and that the treatment activities helped to achieve laboratory content knowledge goals.

Results and Analysis Related to Research Question 2

The second research question was: Do GeoScene applications affect student comprehension and interpretation of geologic phenomena in an authentic field environment? If so, how and why? This question was addressed by analysis of interviews, video recordings, memos and field practical examinations.

Interviews. Selected students from the treatment group (7 of 13) were interviewed and asked directly about the effect of the GeoScene utilizing the interview protocol in Appendix F. Throughout the interview, all of the students interviewed stated that the GeoScene helped them understand the field environment. An example of one of these comments came from Olivia, a highly performing student with no previous geology coursework, who stated:

I would say yeah, because like I said, just understanding it and knowing

the differences and how you described how different rocks came about.

And then, like the strike and dip, I can remember it in my head like clear

now, because that's where I got it. And then taking it out there, and

having that image already in my head from there going outside. I knew

how to position myself, I just had to figure out the compass. Then once

we figured it out, ok, now we're on track and now we can do it. It's

something that's memorable that when you learn it there, it's something

that sticks in your head. So, it's like we referred back to that like when we were out here remember…it's like it stuck.

These interview data supplied a rich fabric to study the learning and comprehension of the students involved in the treatment. After the interviews were transcribed, they were coded using the open and axial coding methods previously described. Seventeen primary codes were established during open coding analysis of the interview transcripts, which were then constructed into four dominant themes during the axially coding process previously described. The four themes were: transitional physical environments, critical analysis, visualization, and communication.

Theme 1: Transitional physical environments. This construct included codes that were linked to being in the outdoor environment, interacting with real materials, and shifting understanding or thinking to an authentic environment. Students made simple comments throughout the interviews like, "you know, you're outside" and referred to the GeoScene as "hands-on." They also made reference to its transitional nature as being "real, almost, " or a "pre-brief" to the authentic field environment. This theme became evident after students were asked to articulate how they felt the GeoScene may have affected their individual learning and ultimate performance in a field environment. Rachel, a highly performing student with a previous geology class, articulated how it shifted the way she thought about the material when she stated: "Being outside, I mean - key. You're actually outside. You're actually seeing something outside when

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you're going to go outside. It shifts the way that you're learning, it shifts

something in your brain." She further offered this exchange:

Rachel: And it's real rock. It's real rock. It is real rock. It's not plastic

that's painted or anything.

Researcher: So, it doesn't have that model effect?

Rachel: Like a model heart with the plastic valves and stuff. Oh, it's real

rock and you really put it there.

Researcher: And the lab is traditional learning, and then you get out and I

say, "identify the rocks."

Rachel: Yeah, the first time out there [at the GeoScene] that's what it's

like. It's like "woah, woah, woah, wait, what?" Which, if I had not been

and gone and seen [the GeoScene] that way then when I went out in the

field I might have gone "woah." You know, I might have done that then.

There is something about that, about actually laying your eyes on the rock

itself, and I'm being kinda woo woo here but I mean if you're actually

looking at the rock, you're seeing the real rock it's not a fake rock. There's

a huge difference there.

Researcher: I think so, rather than a picture or something.

Rachel: We're sensual human beings. We have senses that we don't even

know we have, so we're picking up the energy of the rock. There is

something about it. We're like connecting with it.

Researcher: The physicality of the object, I totally agree.

Rachel: So fake, plastic, or spray-painted is not going to set up that click in your brain.

In the previous dialogue, Rachel suggested that the physical nature of the GeoScene helped her transition physically to the outdoor authentic environment. This idea was echoed by Zoe, a highly performing student with previous geology experience, when alluding to the benefits of the physical proximity of the GeoScene to the laboratory room:

It was nice that you're out there [at the GeoScene] and you can go back to samples [in the lab] that are labeled. And you know what these rocks are and you could just take [the rock] and compare and keep going back and forth [between the GeoScene and the lab]. So when you're in the field, you don't have that luxury. You're not going to have a backpack full of rocks to compare [the real rocks] to.

The theme of transitional space was prevalent throughout all of the interviews, with all students interviewed making statements that supported this theme. The continual references to the space as a beneficial intermediary between the laboratory and the authentic field environment contributed to this theme.

Theme 2: Critical Analysis. Students repeatedly remarked about the complexity of the GeoScene related to the laboratory environment and how they began to understand and process information while at the GeoScene. The critical analysis theme was constructed from codes such as: complexity, understanding through differences and applications, individual processing, and not prescribed or unanticipated activities.

An example of a step through critical analysis was articulated by Dane, an average performing student with previous geology coursework, who shared, "I think it gives you more of a different perspective. You feel like after you are done, you are smarter. [The GeoScene] was different, it was a little bit trickier to figure out…like these [rocks] are both the same, how?"

Eden, an average performing student with no prior geology experience offered this explanation of her expectations and how the GeoScene affected her thinking:

Just because you know you're outside and you're…you can't…in the lab, you can expect all these different samples and expect it to be…I don't know how to explain it. But it seems more simple, because everything is laid out for you. But when you go outside and you go out to the GeoScene it's not all laid out of you. It's not like a lab sample or lab trays placed in front of you and you're supposed to...you actually have to think more.

Roman, a low performing student with no prior geology coursework stated, "Well, I think it is like I said, we're not sitting in a lab and we have everything that we expect to have in front of us. By putting us outside, you kind of put us in a different environment where we have to think about it on our own."

These students show that the individual processing and non-prescriptive nature of the GeoScene forced them to think differently than they had during the normal laboratory time. Though no new material was taught at the GeoScene, it was perceived to be more difficult and complex, which benefitted the student's understanding.

Two of the students interviewed did indicate that they felt that the GeoScene was too simplified from the true field environment, and that it therefore was not as beneficial to helping them transition to the field. Both were low scorers on the field practical examinations. Boris, who had no prior geology coursework stated, "It's interesting, [but] it's cut and paste though. You look at the granite or marble [at the GeoScene] and you won't see the same thing out in the field." Boris repeatedly referenced that the field was "not as obvious" and "much harder." Roman, who also struggled on the field practical examinations stated that he felt the GeoScene "had the same effect as checking the rocks in the containers because they were still just in the specified positions." While he "enjoyed" the GeoScene aspect of lab, he felt "it helped just as much [with the field] as the inside [laboratory work]." This disconfirming evidence contradicts the interpretation that the GeoScene helped all students learn to critically analyze rocks and structures introduced in the laboratory setting.

Theme 3: Visualization. The visualization theme was constructed from codes including: spatial, 3-dimensional, understanding through seeing, and size. Understanding the material through seeing the GeoScene due to its visual nature was a prevalent feature in 5 out of 7 of the interviews. Boris offered that the GeoScene was "more visual" when responding to a question of how it may have helped him in the field environment. Dane remarked that "[Geology] was easier to understand in the field after you saw it all like kind of in the field, you already got a taste of it" to the same question. Olivia spoke several times about

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understanding geology through visualizing throughout her interview. When asked initially what she thought of the GeoScene as a part of the lab, she replied:

> When you described to us how the different rocks changed, it was actually there [at the GeoScene] and you could see it and you could see where it came together, versus just describing it and not knowing or not being able to see because we can't go and dig up the side of a hill. It's right there. For me, it just enhanced it and it was more understandable. And I could relate to it and I could see, ok, this is how it happened. And that's how I remembered a lot of stuff was just remembering you know the things that you described to us or if we had questions about it and you clarified it for us. That helped me when we were out [in the field].

Zoe responded to the same question by saying:

> The relationship of it, it's not just layered of rocks. There's a relationship between the metamorphic and the igneous and it like comes together and you're like, "OH!" I definitely see it. I thought it was great…and it's taking it from…you know…we're used to seeing it in the book and on pictures…so it's actually live…somewhat. It was absolutely great…and I get it. You can memorize stuff all you want and not really know it. You just memorized it. And you can do well because you know what to say. But just actually seeing it and being able to test it is something else.

Since the second research question was related to how the GeoScene affected performance in a field environment, all of the students interviewed were selected from the treatment group. However, one student approached the

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researcher directly in front of the camera during the video recording of the control

group application, and the conversation was recorded and transcribed. It is

included here, because it highlights a need for visual materials within the control

lab. Jack, a highly performing student with prior geology coursework,

approached after finishing his last laboratory assignment (L6) and engaged the

researcher:

> Jack: You should make a model of this, like a live model.
>
> Researcher: So you could mess with [the rocks]?
>
> Jack: So I can see them. You know the ant[farms]. You know the
>
> ants…the things they have at the Science Center? (He gestures with his
>
> hands). You need one of those but with rocks. Wouldn't that be nice?
>
> Researcher: That would be nice!
>
> Jack: I put that in my recommendations.

The theme of visualization is strongly represented throughout the

interviews, when responding to a variety of questions. None of the treatment

students interviewed made any statements that were coded contrary to this theme,

like Jack expressed in the control group.

Theme 4: Communication. Students repeatedly referenced specific

instances of learning involving discussion with other students, including their

specific lab partners and others in the laboratory environment. Rachel remarked

that, "[It was cool] watching everyone else figure [the GeoScene] out." Eden

commented about the benefits of having partners by saying, "I think having the

partners for [understanding how to hold the compass] worked, we kind of relied

on each other." Others just spoke inclusively of their lab partners when replying

to questions, using the pronoun "we", and others spoke of specific people by

name when describing the lab process. For example, Olivia stated, "[In the field]

Rachel and I referred back a couple of times [to the GeoScene], ok, this is where

we were by the rock wall." Zoe spoke of the consistent nature of the class

communication when she said:

> I know we'd all go back [to the laboratory room] and then we'd talk to
>
> each other trying to figure [the GeoScene] out. I think on [the GeoScene]
>
> we were all working together somewhat and not somewhat. Because, I
>
> know that we were having conversations outside to try to understand [the
>
> GeoScene] and I know that [those conversations] really helped. So, when
>
> we went out [to the field environment], I know that was really helpful,
>
> because we were all already always working together."

Students within the treatment group consistently spoke to each other

throughout the laboratory, and this theme was represented in the interview data by

four of the seven interviewees.

Video recordings. The video recordings were analyzed with the

procedure outlined in the methods section. One of the preconceived themes that

the videos were being analyzed for was the notion of geogesturing. Throughout

all of the videos, there were only seven total instances of geogesturing, and four

of those were in response to the geogestures made by the instructor.

During the second reading of the video recording annotations, themes

were constructed using the open and axial coding previously described. These

data were grouped into two major themes: communication and movement. The theme of communication referred to the way students interacted verbally with each other throughout the innovation. Although audio throughout the video was spotty, and usually not discernable, conversations within and between groups of students could be established. The theme of movement was constructed through grouping descriptions of how students moved throughout the space. Due to the nature of the video camera, the physical movements of the students were easily observable. Within these two themes, students within the control and treatment groups behaved differently throughout the intervention, and these differences are highlighted in the following paragraphs.

     Control group. Control group students usually worked with lab partners throughout the laboratory environment, although many of them also worked independently for large portions of the application. The application for the control group was often centralized in one area of the classroom for ease of capturing the video. This resulted in several of the labs having large groups of individuals surrounding the application materials during portions of time. Students were free to pick up and remove samples to take them throughout the room, and also free to compare application samples to standard laboratory samples, but they rarely did this. In general, students would approach the application materials and stay there until finished with the application exercise. Their movement was described as very low. Some students would pick up individual samples but others would never touch them.

The students would engage in quiet conversation that could often not be clearly overheard by the camera though it was less than ten feet away. This was not a phenomena observed just when the students were directly in front of the camera, as the conversation in the room rarely peaked. The students would speak within small groups consistently, but they were observed communicating with someone outside of their own group rarely. Even when students were in large groups at the activity samples, they did not engage in conversations outside members of their own groups. Three students (of 12 in the class) appeared to speak rarely to other students within the class. The researcher was in the laboratory space constantly to answer questions or clarify in discussion, but was not engaged consistently. This behavior was pervasive throughout the study labs (L3-L6).

Treatment group. Treatment group students also worked in groups, and occasionally as individuals. Because the activity area was larger for the treatment group, the camera was located further away. Still, conversations and movements could be observed.

Some students moved throughout the area consistently, while others stayed in a more confined area. Throughout the lab, students regularly returned indoors to compare laboratory samples or retrieve materials, regardless of their movement outside. Students were often seen to move to engage other students in discussion.

Though the camera was further away than in the control group, portions of conversations and discussions could be regularly overheard. Initially during L3,

students worked largely within their own lab groups, but some went outside their groups to explain concepts or as questions of other students. In one instance during L3, a student left the GeoScene for a few seconds and then returned with another student in another group who appeared to explain portions of the lab. As subsequent labs (L4-L6) were completed, students began regularly engaging students outside of their original partners or joining other groups entirely. They shouted across the activity area to each other. The researcher was intermittently available for discussion, shifting between the indoor laboratory space and the outdoor GeoScene space, and was regularly and consistently engaged during the time present at the GeoScene.

Memos. The memos were axially coded at the time of transcription, since they were processed themes based on observations (Gay, Mills, & Artisan, 2008). Memos were written at the end of each week, after both the control and treatment groups had completed L3-L6, as well as the two field practical examinations. From the memos, the single most consistent theme was communication. The memos noted that the treatment group constantly engaged the researcher in a way that observational notes were difficult to take. Additionally, the room was continuously described as "loud" and "engaged." The control group was consistently described as quiet and it was repeatedly noted that they did not ask questions. The control group completed the traditional labs (L3-L6) faster than the treatment, while the treatment completed the application and field activities faster than the control.

During the field practical examinations, it was also noted to be very little communication within the control group. While students were asked to work alone, it was noted that students within the treatment wanted to interact with each other and had to be told to wait until the end of the exercise. During the interviews, Roman commented that he didn't expect to have to "work alone" on the field labs and he felt that made completing them much more difficult.

Field practical examinations. The field practical examinations were used to define and determine the trend of student performance in a field environment (Appendix D). The results of the two field practical examinations were aggregated for analysis, using the procedure described in the methods section. The combined field practical yielded a high degree of internal reliability, $\alpha=0.80$, with $\alpha=0.77$ for the control and $\alpha=0.78$ for the treatment group (Cronbach, 1951). Table 6 shows the results of the field examinations using a Mann-Whitney U-test to compare performance between the control and treatment groups. Each of the constructs related to the individual laboratories (L3-L6) were also analyzed using the same method. Due to the small sample size, a Cliff's δ was calculated to lend statistical power to any p value ≤ 0.05 (Hess & Kromry, 2004). According to Hess and Kromry, a small effect size would have of delta value of 0.147, a medium effect size would have a delta value of 0.33, and a large effect size would have a delta of 0.474 (2004).

The treatment group appears to have significantly outperformed the control group on the Field Practical Examinations at the $p \leq 0.01$ level, with a large effect size ($\delta=0.570$). Additionally, the treatment group appears to have

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outperformed the control group on all individual constructs as well, but

significantly at the p≤0.05 level for only L4, which also showed a large effect size

(δ=-0.519). The results from Laboratory 4, which was linked to spatial skills and

3-dimensional visualization was also subtracted from the overall content score, to

be sure that this one measure did not account for the statistical differences seen in

the overall instrument. Removing all data from L4 in the analysis still revealed an

apparent statistically significant difference (p=0.04) in the remaining content,

with a large Cliff's delta (δ=0.481).

Table 6

Comparison Control/Treatment Group Performance on Field Examinations

Examinations

Factor	Group	n	Mean	Median	SD	p value	δ
All	Control	12	33.67	32	10.03	0.01**	0.570
Field	Treatment	13	44.46	43	9.72		
L3	Control	12	7.92	7	3.97	0.17	
	Treatment	13	10.62	10	4.93		
L4	Control	12	8.00	8	2.49	0.03*	0.519
	Treatment	13	10.38	11	2.53		
L5	Control	12	10.42	13	5.50	0.06	
	Treatment	13	14.00	14	3.56		
L6	Control	12	7.33	7	3.09	0.08	
	Treatment	13	9.46	10	2.76		

Note: Numbers reported are points received on the Field Practical Examinations. Total possible was 80 points. Raw data available by contacting author.

** Indicates significance at p≤0.01, two-tailed.

* Indicates significance at p≤0.05, two-tailed.

The field practical examinations also had a 5-point Likert scale survey attached to capture self-efficacy related to the content covered in L3-L6 (Appendix D). These data were analyzed utilizing a Mann-Whitney U-test, and revealed no statistical difference between control and treatment groups (p=0.73).

Interpretations of data for research question 2. There were several data sources utilized to answer Research Question 2: Do GeoScene applications affect student comprehension and interpretation of geologic phenomena in an authentic field environment? If so, how and why? These primary data sources included: interviews, video recordings, and memos, and were further supported by the field practical examinations.

The qualitative data sources revealed that students felt the Geoscene provided them with an opportunity to physically transition to authentic environments by providing them with an intermediary step. The aspect of being outside, working with real rocks, but still proximally close to the laboratory environment, helped the students successfully shift their thinking from that laboratory environment to the field.

Student responses also suggested that the GeoScene supported them to understand the complexity of geology, even though they were not presented with new materials in that environment. The GeoScene experience challenged them to elevate their thinking process where they recognized that they had to approach the problem critically and independently.

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Additionally, the GeoScene provided a more complex visual representation of laboratory materials, but not as complex as a true field environment, which also allowed the treatment students to successfully transition to the field. This theme is further confirmed by a control group student who recognized that he just could not visualize what the rocks looked like and that he felt this process would help him understand the concepts better if he had a visual model. Spatial awareness and 3-D visualization were themes included within the visualization construct from the interviews.

The field practical examinations indicate that students involved in the GeoScene application performed statistically significantly better in the field environment ($p \leq 0.01$). This is supported by a large Cliff's delta ($\delta = 0.507$), which is an estimate of the magnitude of the differences (Hess & Kromrey, 2004). The use of the Mann-Whitney U-test assumes heterogenity and non-normality of data, which is an appropriate analysis comparing samples with a small N (Fay & Proschan, 2011). Though this calculation is more conservative than a traditional t-test, it still yielded a statistical significance when comparing performance in the field environment. The large effect size lends statistical power to the small N of the study and supports the interpretation that the treatment group performed better in an authentic field environment although by itself does not necessarily indicate that the GeoScene is the sole factor responsible for the difference.

Self-efficacy was repeatedly measured throughout the study, but there were no differences captured within the data. One student did comment that completing the GeoScene activities did make him "feel smarter," but this is not

supported by any other data. Additionally, though measures were taken to capture the existence of geogesturing in the visual recordings of the innovation, there was no evidence of gesturing related to geologic concepts throughout the study.

Conclusion of Results and Data Analysis

This chapter systematically addressed the research questions:

1. Does replacing classroom-situated laboratory exercises with GeoScene applications affect student comprehension and interpretation of geologic phenomena in the laboratory environment?

2. Do GeoScene applications affect student comprehension and interpretation of geologic phenomena in an authentic field environment? If so, how and why?

The participants involved in the study were compared at the beginning of the intervention to attempt to determine whether either group appeared to have differing cognitive and demographic attributes that could potentially skew results and interpretations of data collected. Because there is an inherent limitation when interpreting quantitative data with a small sample size, as in this study, the research questions were primarily addressed with qualitative data sources and supported with quantitative ones. Though equivalence cannot be assumed due to the limitations of sample size, the control and treatment groups were observed and measured in the context of ACC, and appeared to be equivalent by all measures.

Both qualitative and quantitative results suggest that students involved in the treatment group learned laboratory content comparably to those in the control, supporting an assertion that the GeoScene applications were an acceptable replacement to similar laboratory activities. They both also help triangulate to the conclusion that the GeoScene helped student comprehension and interpretation of geologic phenomena in an authentic field environment. Several themes were identified to address how the GeoScene may have caused this phenomenon, namely: acting as a transitional physical environment, encouraging students to critically analyze their surroundings, allowing students to better visualize geologic process, and improving student to student and student to teacher interactions.

Chapter 6

CONCLUSION AND DISCUSSION

This study was developed to focus on whether an artificial outcrop at

ACC, called the GeoScene, could help scaffold student learning in an introductory

geology course from a laboratory environment to an authentic field environment.

The study was designed as a mixed-methods action research study, where the

researcher was also a participant within the study. Two sections of the same

geology laboratory course, taught by the researcher, were selected for the study,

one designated as a control and the other a treatment group.

The study was based on the tenets of experiential learning, highlighted by

John Dewey (1944), subsequently expanded by Kurt Lewin (1948), and later

David Kolb (1984). Constructivist pedagogies informed the concept of the

intervention, emphasizing that the students' construct meaning through interaction

with stimuli, whereas the design of the study followed strategies suggesting the

integration of activities throughout the learning process when conducting

fieldwork in natural settings (Gage & Berliner, 1998; Orion, 2007). Several

known barriers to learning geology in a field setting were addressed and measured

throughout the study, including: spatial ability, self-efficacy, and novelty space.

The methodology separated the study into three components. First, an

attempt was made to determine whether the control and treatment groups

appeared to be statistically similar to each other at the beginning of the study,

though they were not random samples. The groups participated in a pre-test

where their geologic concept knowledge was measured, as well as demographic

information collected. Through a series of statistical analyses, which included: Mann-Whitney U-tests of the beginning content knowledge, self-efficacy, novelty space concept, and age of the participants, and chi-squared analysis of demographic information, it was determined that these groups appeared to be equivalent. One major drawback to any statistical analysis performed was the low number of participants, which affects the validity of any quantitative claim, with thirteen in the treatment and twelve in the control group. Additionally, there are innate differences between all populations that are not measureable through quantitative means. Though every measure suggested equivalence of the groups, and they were treated as equivalent in subsequent quantitative analyses, the research questions were addressed primarily with qualitative data sources.

Research Question 1 focused on whether the GeoScene treatment adversely affected students in the laboratory environment by taking time away from traditional laboratory activities and replacing them with those at the GeoScene. All seven of the students interviewed stated that the GeoScene helped in their understanding of the laboratory activities, stating specific examples of how improvement of understanding was made. Additionally, though treatment students spent less time on the traditional laboratory activities, they performed as well on the laboratory exam. This suggests that students mastered the same information during the course. These findings suggest that the GeoScene did no harm to these students in their understanding of laboratory materials, and could potentially be an adequate replacement to the additional traditional laboratory activities for future geology classes.

Finally, the question of whether the GeoScene affected comprehension and geologic understanding in an authentic field environment was addressed. The students' ability to describe and understand the geology they saw at an in situ local geologic outcrop was measured utilizing interviews, memos, student reflections, and field practical examinations.

The qualitative data suggest that the GeoScene may have been beneficial for improving outcomes in a field environment, and the field practical exams seem to corroborate this result. From interviews conducted after the intervention, students revealed that the physical nature of the GeoScene helped them to transition their understanding from the laboratory environment to the field environment. From the interviews, the themes of: transitional physical environments, critical analysis, visualization, and communication were constructed. The students identified the GeoScene as providing a physical environment where they could transfer their laboratory learning from an indoor environment to an outdoor one. The theme of critical analysis refers to the student's ability to evaluate complex geologic concepts that had previously been described. Students repeatedly declared that the GeoScene helped them to visualize geologic processes and events, and that the 3-dimensional aspect of the structure aided in their understanding. Finally students indicated that they learned at the GeoScene through communication with their peers.

The first two themes link directly to Kurt Lewin's (1948) ideas of experiential learning by connecting the abstract to the concrete through physical activities. Lewin claimed that the "here and now concrete experience to test and

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validate abstract concepts" is of the utmost importance when learning (in Kolb, 1984, p.21). The students had a direct, physical, application of abstract concepts in the laboratory environment. This experience, therefore, helped them to learn, and deepen their understanding, through application. Kolb (1984) also claims that the immediate experience gives the students a reference point to refer to when moving on with their understanding. The students articulated the idea of the GeoScene providing a physical reference point for learning that they could remember later while in the field environment.

These themes also relate directly to Orion and Hofstein's (1994) concept of novelty space. The authors state that students with little to no exposure to the outdoors have more difficulty making cognitive gains in the outdoor environment. By transitioning the students through the GeoScene, they were exposed to the outdoors, which mitigated this factor in the field. Repeatedly during interviews student remarked that the outdoors environment of the GeoScene helped them later in the authentic field environment by adjusting their thinking to that environment.

The field examinations revealed that the treatment group appeared to have significantly outperformed the control group ($p \leq 0.01$, $\delta = 0.507$) in an authentic field environment, although the low N involved in the study allows for alternate interpretations, but the finding supports the themes constructed in the qualitative data.

The results of the study suggest that the GeoScene may have improved performance of the treatment students in the authentic field environment by

helping them to transition between the concrete and abstract realms of geology through experiential learning in an outdoor space.

Discussion

This discussion expands on some of the results of the data collected in this study, and suggests new directions of potential study. It also expands on limitations of the study and lessons learned.

Communication. Within all of the data, the theme of communication was constructed several times within the interviews, video recordings and researcher memos. Communication is defined as student-to-student interaction and student-to-teacher interaction. This theme was supported in both the analysis of the videos and the researcher memos, as well as constructed within the interview data. While students in both the control and treatment groups communicated with their lab partners throughout the exercises, the students in the treatment group communicated more with others outside of their lab partners. Additionally, the treatment group students also engaged the instructor more throughout the activity.

Kurt Lewin (1948) might say that learning and the construction of knowledge at the GeoScene occurred through the interrelation of the individual and the environment they are in, and that a powerful dynamic was created within the group because they were dependent upon each other for achievement. It is not understood whether the communication of the treatment students in this study affected their learning of the GeoScene, or if, conversely, their learning at the GeoScene affected their communication. There is a correlation between communication and outcomes in the field environment, but that correlation was

only observed rather than studied, so causality could not be determined. However, this link could be important for further study and expansion in this field.

      Spatial skills. Good spatial skills are linked with mastery in geology, but identifying and measuring specific spatial skills within this study was a difficult task. The PVRT mental rotations test was designed to measure spatial skills in the absence of analytic processing, which was why the test had a strictly enforced time limit for completion (Bodner & Guay, 1997). However, in the authentic field environment, there was no time limit for the assessment of three-dimensional objects. While the literature supports that mental rotation ability is the primary ability necessary for spatial analysis, the need to quickly rotate objects is negated during actual geologic assessment in the field and can be replaced by analytic processing. For this reason, contrary to prevailing literature, the PVRT may not adequately assess a student's potential for spatial analysis that has no associated time limit. The reliability of the PVRT was suspect, as previously discussed, so there was no way to objectively compare the incoming spatial ability of incoming students involved in the study.

      However, qualitative data collected throughout the intervention suggests that the spatial skills necessary for determination of strike and dip and geologic structures may have improved through interaction with the GeoScene. In the interview process, students repeatedly remarked that the concepts mapped to L4, which was a lab that focused on geologic structures and spatial skills, were the most challenging for them. Eden commented that, "the one thing that I struggled

with in the lab was the compass." Olivia related as well, stating: "I was like, I know you stand like this and we were trying to figure out how to use a compass again. We got it when we were outside at the [GeoScene], but then when it came to actually being [in the field] and it's not right next to you. It was kinda hard to get it in the right direction again." This was consistent throughout 5 of the 7 interviews. Overall, students identified the strike and dip (L4) as being the single concept that they struggled with the most, but also one that stayed with them even after the laboratory was over. Boris stated that he gained a further understanding of strike and dip while at the GeoScene. When asked to elaborate, he said, "I was kinda like scratching my head [at first]…and then it started to make a little bit more sense. It was confusing at first. But then [at the GeoScene] I got it." Olivia went on to say that the GeoScene helped her with L4 by reporting, "I can do [strike and dip] on the [GeoScene], but I just gotta do it on a bigger scale." These statements are examples of how the treatment students identified their struggle with understanding strike and dip and their subsequent improved understanding through interaction with the GeoScene.

This theme was also identified in the memos. It was noted that both classes struggled with strike and dip during the laboratory portion of the class, and that treatment students Maude and Anthony seemed so frustrated that the researcher thought they might leave the laboratory without completion. The memos also revealed that the GeoScene seemed to clarify strike and dip for some of the treatment students, noting that something "seemed to click for Olivia" and that "Roman was so unsure through the whole lab that he followed [the

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researcher] around to check every answer, but seemed to get it in the end." In fact, both Maude and Anthony showed an "improved attitude" toward L$ after their time at the GeoScene.

Both control and treatment students performed similarly on the content knowledge portion of the pre and post-test for those skills related to L4. However, treatment students did perform statistically better in the field with respect to the materials conceptually mapped to Lab 4 ($p \leq 0.05$), which aids in the suggestion that students in the treatment group had an improved understanding of L4 concepts.

While a determination of students' incoming spatial ability could not be established for this study, it appears that both groups had similar abilities relating to strike and dip and geologic structures at the beginning of the class, and that they all struggled with the concept during the laboratory portion. However, students in the treatment group went on to identify points of understanding that occurred due to interaction with the GeoScene. The field practical exams help strengthen the idea that they mastered this skill preferentially to their peers and could perform this task in the authentic field environment.

Gender. There were some curious gender differences that emerged within the data collected for this study. Though there was no difference in pre-test scores, females in both the control and treatment groups outperformed the males, regardless of previous coursework in geology, on both the post-test and the field practical examinations. Though most of these differences were not statistically significant, they did show up consistently through the data. Additionally, the

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treatment group females interviewed showed a high degree of enthusiasm for the course, while the males showed less enthusiasm. As a female researcher, this sparked my interest, as women are traditionally perceived to be at a disadvantage and under-represented in the sciences. While this possibility was not systematically tested, it could be another avenue for exploration in the field of geoscience education. For example: Does the gender of the instructor relate to the outcomes of female students in introductory geology courses?

Lessons Learned and Future Directions. The previously presented literature indicated the importance of geologic field trips to the study of geology, and also highlighted the difficulties with teaching and learning in authentic field environments. This study suggested that at ACC, the transition between the laboratory and field environment may be improved by utilizing an intermediary step, namely the GeoScene. While using rock gardens and other outdoor faux geologic environments in geology courses is not a new concept, evaluating how students learn in those environments is, as it pertains to continuing to authentic geologic terrain. In this way, this exploratory evaluation contributes to the field of geoscience education.

Advice to the future builder of a GeoScene equivalent, or modifying an existing one, would include utilizing real rocks, rather than plastic or painted facades, as this aspect was repeatedly supported in interview data with the participants. Additionally, researcher memos and student interviews suggest these terrains should not be too abstract in nature, requiring the student to visualize geologic structures or relationships on their own, but rather explicitly

showing those relationships and allowing the students to physically explore them outdoors. Though the physicality of the GeoScene was irreplaceable for the students involved in the study, technological advances offer promise that some of the transition to authentic environments might be accomplished through virtual experiences.

The selection of the authentic field areas could also be another avenue of future study. Geologic terrain is incredibly diverse, with some places representing more abstract geologic concepts. In this study, the relationships between rocks were generally easy to assess, but the second field area was more abstract in nature. It would be an interesting expansion to determine differences in the way students process learning in more geologically abstract terrains, and the role the GeoScene might play in that expansion.

Action research is cyclical in nature, with a focus on reflecting, planning, acting, and observing, which then informs future cycles of research. As a result, this study was one cycle of action research, informed by a previous cycle, and implies that this analysis and design will continue in future cycles. What are the next steps and lessons learned in my own classroom, and what changes will I make? One of the issues that students face when content is very challenging is cognitive fatigue. The classes studied were two hours and twenty minutes in length, which represented a long expanse of time for student to sustain thoughtful focus. The next change that will be made to these classes is to split the laboratory course into two sessions per week, each one hour and fifteen minutes long. This

will hopefully mitigate the fatigue experienced over a single long classroom period and allow for more gains for the students in multiple shorter segments.

Final Thoughts. My course is quite likely the last geology, or even science-related, course that most of my students will ever participate in. My interest is in achieving the largest learning gains possible within the course of a 16-week semester. I am confident that utilizing a structure like the GeoScene is only one way to improve learning in the field for students in geology, and there are many other learning tools that can be explored and improved. However, I do believe that the GeoScene helps to accomplish this task, and I intend to continue to explore the connections and transitions between traditional education settings and authentic learning environments in the future.

We live on the Earth, and, as such, cannot be separated from it. Though students may not take another formalized course in geology for the rest of their lives, they will never be able to escape being immersed in the Earth. As an educator, helping a student to gain an appreciation of geologic processes, which will stay with them for the rest of their lives, is truly my greatest passion, and the inspiration for this and subsequent works.

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APPENDIX A

CONSENT AND DISCLOSURE FORM

August 20, 2011

You are invited to participate in a research project on learning in geology. I, Merry Wilson, faculty member at Scottsdale Community College, will be conducting this project.

In this project, I will administering surveys, observe and take notes during class, visually record class activities, collect student work, and conduct interviews. All of these activities will occur within the confines of normal class time. You also may be selected to participate in a 5-10 minute interview, which will be audio-recorded. The audio and visual recordings, as well as all other information obtained during this research project, will be kept secure. The audio and visual recordings will be kept in a locked file cabinet and will be accessible only to project personnel, which will be transcribed and coded to remove individuals' names and will be erased after the project is completed.

I do not anticipate any risk to this study greater than those experienced in normal life and I anticipate that the results will increase my understanding of how students learn in the geosciences. The results of this study may be used for a dissertation, a scholarly report, and/or a journal article and conference presentation. In any publication or public presentation, pseudonyms will be substituted for any identifying information.

You are required to participate in all classroom and course activities during the semester, but your participation in this research project is completely voluntary. If you opt out of the research project, your information will not be used. I will not know who has consented to be a part of the research study until after final grades are assigned in December.

If you have any questions about this research project, please contact me by telephone at 480.423.6392 or by e-mail at merry.wilson@sccmail.maricopa.edu.
Sincerely,

Merry Wilson

_____

Please check one box below:

☐ I agree to participate in the research
☐ I do not agree to participate in the research

I have read and understand the above information and voluntarily agree to participate in the research project described above. I have been given a copy of this consent form.

_____
Signature   Date

I do agree to have the interview audio taped for the purposes of transcription.

_____
Signature   Date

I do agree to be visually recorded for the purposes of transcription.

_____
Signature   Date

If you have any questions about your rights as a research participant please contact: 480.731.8295 or irb_office@domail.maricopa.edu.

APPENDIX B

SAMPLE LABORATORY

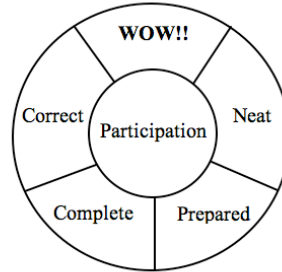**Name:**

Lab 4:
Strike/Dip and Geologic Structures

Lab Partners (only 2 or 3):

Self-Monitoring: Can you read a compass? Draw an arrow indicating which direction is North in the classroom in which you are sitting.

If you were outside, how would you be able to tell which direction is North?
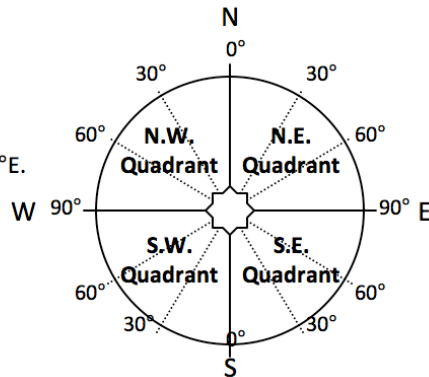
Fun with Foam!!!
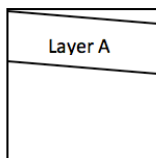As directed by your instructor, orient your foam board at the angle and direction specified.

Compass Directions and Quadrants

Starting from the center star in the middle of the compass

Draw an arrow that points N30°E, S45°W, N60°W, and S80°E.

In the Boxes below, draw a layer at 30°, 45°, 80°, and 90° dip angle from horizontal. An example at 10° is given below.

Layer A
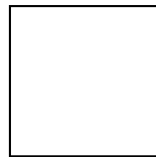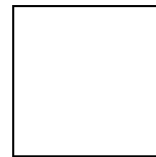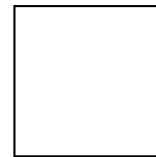
10°   30°   45°   80°   90°

Strike and Dip

Strike and Dip refer to the orientation or position of a geologic feature.

The strike of a bed, fault, or other planar feature is a line representing the intersection of that feature with a horizontal plane.

The dip direction is the direction the dip is plunging. The dip angle is the degree from horizontal.

Strike and dip are always perpendicular to each other.
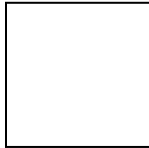
The strike and dip symbol is drawn like this:
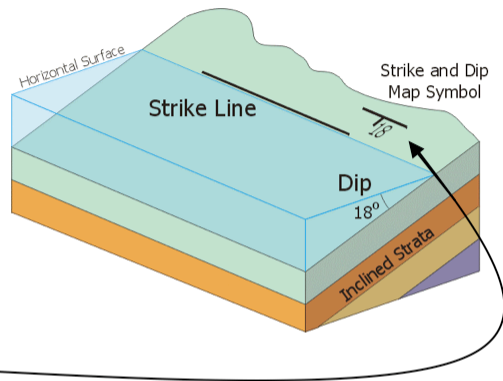
Draw the appropriate Strike and Dip symbols in the boxes provided below. An example is provided.

Strike: N45°E Dip: 20°SE	Strike: N45°W Dip: 20°SW	Strike: S10°E Dip: 80°NE	Strike: S80°E Dip: 80°NE	Strike:S45°W Dip: 45°NW
20				
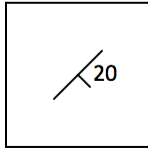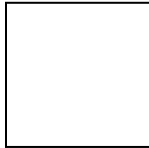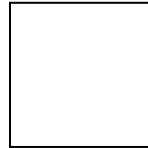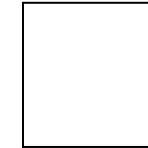
Special Cases:
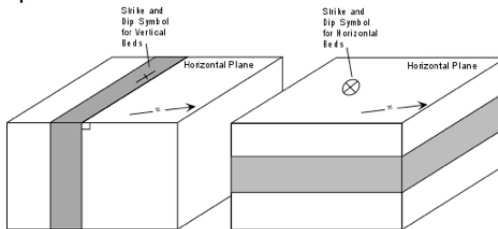
*Reflection:* Define Strike and Dip in your own words.

Do you feel you understand this concept, why or why not?

Measuring Strike and Dip with a Compass

Brunton Compass: a geologist's best friend – go get one.

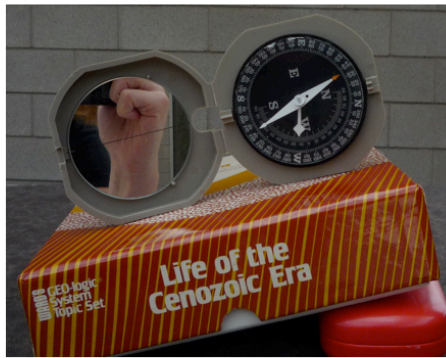The whole compass is offset from True North by 13.5° in AZ due to variability in the Earth's magnetic field.

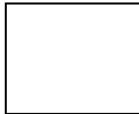What is odd about this compass face?

(Think about cardinal directions...)
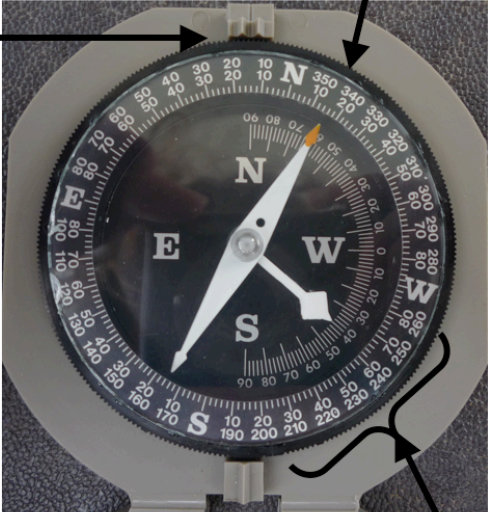
Divided into Quadrants, as well as 0° to 360°.

The compass measures dip angle too!!!

How much is this box dipping? Look here:

Write out the strike and dip in words for the compasses shown. Draw the appropriate strike and dip symbols.

Strike	+	Dip	=	Direction / Degrees
(Compass lying flat)		(Compass at angle)		Strike & Dip Symbol

Strike: Always read along the outside ring (because it is set for magnetic declination). Notice that N15°W and S15°E are the same reading. It doesn't matter which one you use, but always start with N or S.

+

Dip: For this measurement, assume the rocks are dipping NE (you wouldn't know this from this picture but would be able to assume that it was either NE or SW because it is always perpendicular to strike...)

=

Words:

N15°W, 13°NE

- - - - - - -

Symbol:

13

Strike: Always read along the outside ring...

+

Dip: Assume NE for this picture.

=

Strike: Always read along the outside ring...
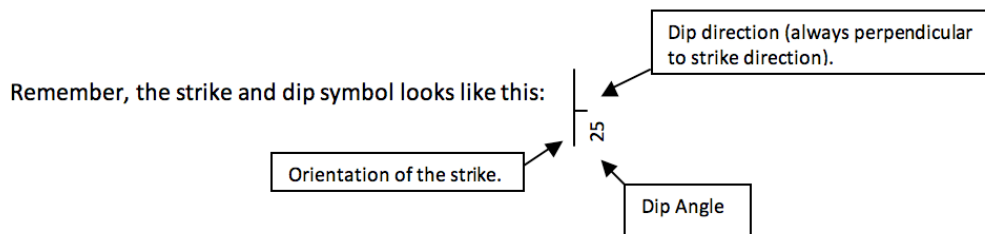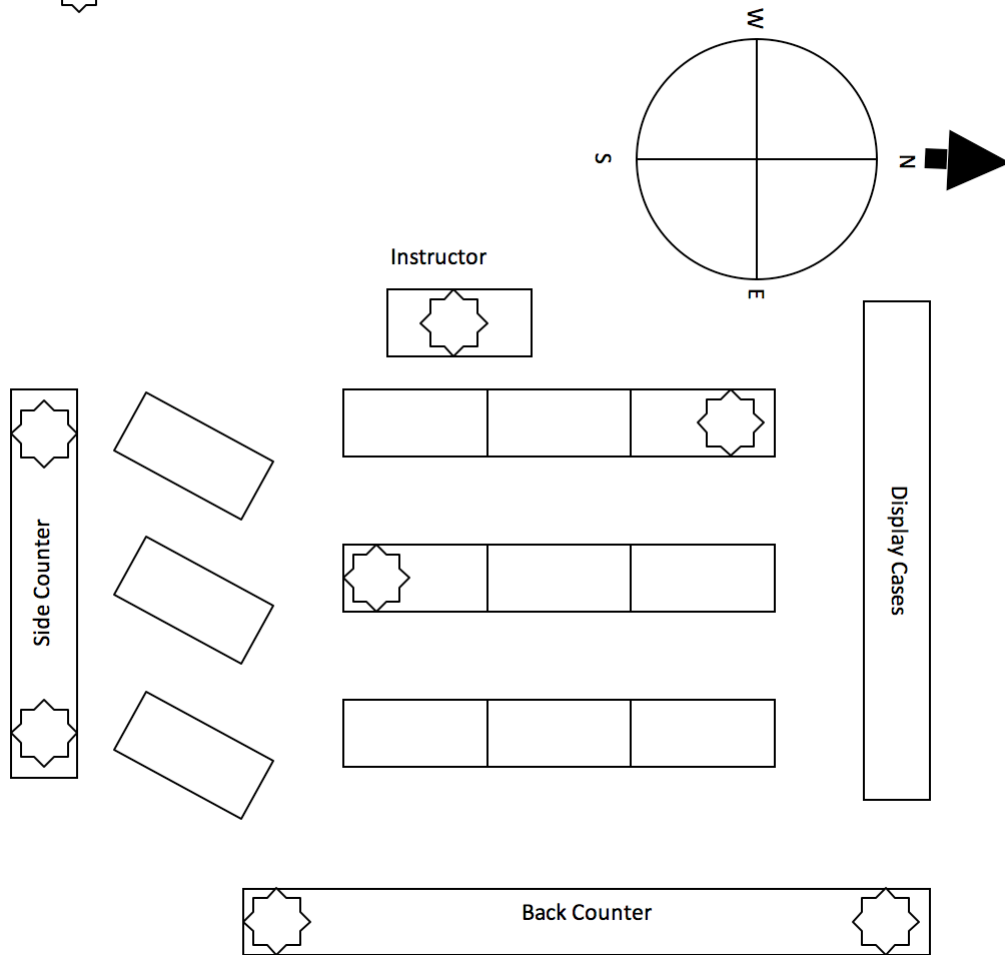
+

Dip: Remember "Special Cases" on page 18.

=

20

97

Around the room are several foam structures. Measure their strike and dip and record them in the [symbol] on the map of the room below. Orient your paper North to help you.

Instructor

Side Counter

Display Cases

Back Counter

Remember, the strike and dip symbol looks like this:

Dip direction (always perpendicular to strike direction).

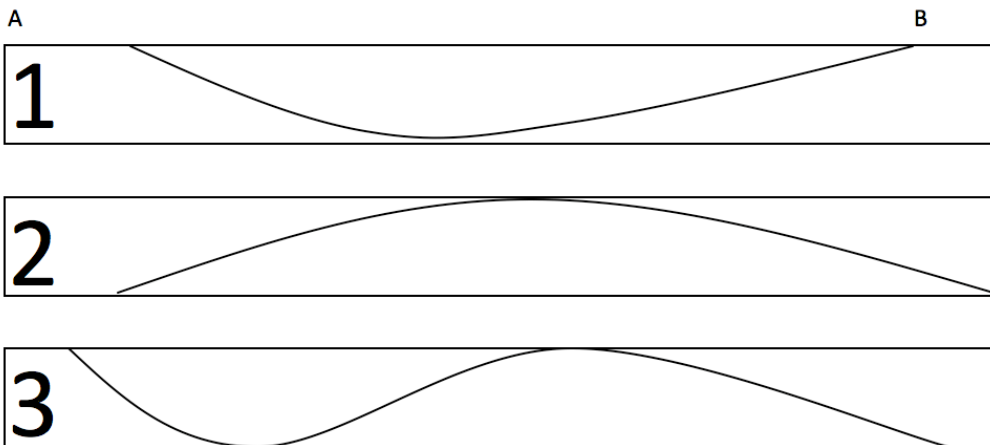Orientation of the strike.

25

Dip Angle

21

Translate your strike and dip symbols to this smaller drawing.
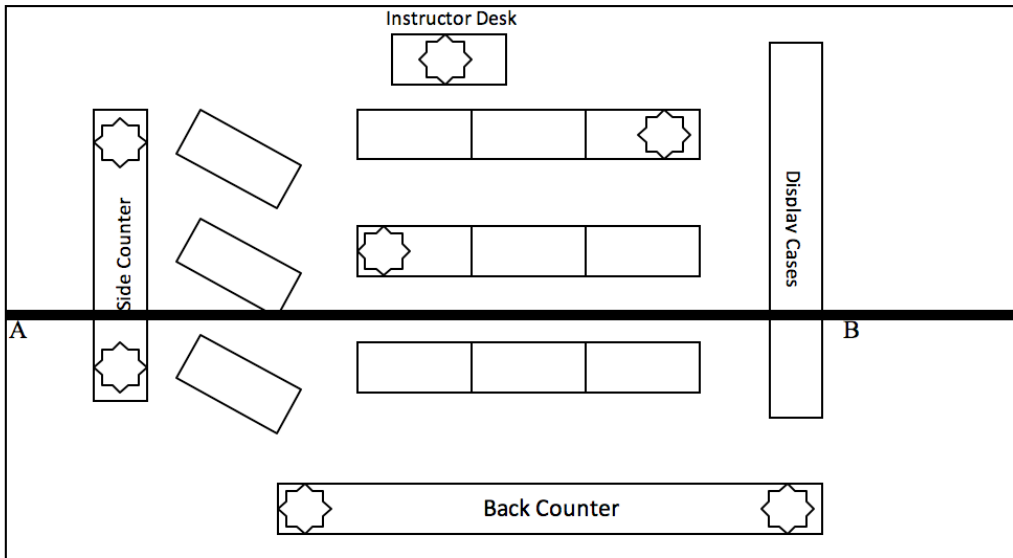
Map View

Above is a map view. Which of the cross-sectional (side view) drawings below most accurately represent the appropriate dip of the rocks along line A-B.

Self-Monitoring: How do you know this?

Why Rocks Break or Deform

Rocks break or deform under stress. *Stress*, technically speaking, is a force applied over a given area. Pressure and stress are actually the same thing. Examples of stresses would be compression, tension, and shear. Different rocks don't necessarily behave the same under similar stress.

1) Think about chewing gum. Under what conditions could you make it more difficult to stretch or squish? What makes it softer? What causes it to break?

2) Now, think about rocks in relation to chewing gum. Obviously, rocks are harder, but under what conditions would they soften? Why would they break?

3) Generalize what you have thought about in relation to the strength of rocks (or of any solid). What variables (conditions) control whether they are soft or hard or if they would break?

4) How would you apply the terms plastic/ductile and brittle to what you learned above? (What makes substances behave ductile or brittle?

Blocks and Foam
Get a set of blocks and flexible foam.

Hold the blocks upright in front of you, looking at the rock patterns on the side. Compress the blocks by moving your hands toward each other and allowing the blocks to slide against each other. Draw what you see.

> Cross-Sectonal View

Now move your hands away from each other and draw what you see.

> Cross-Sectonal View

Set the blocks down on the table in front of you and notice that as the blocks move up or down, the map view (top surface) does not change. If you move the blocks so they slide past each other, the view changes. Do this and draw what you see

> Map View

Take the flexible foam and hold it up in front you. If you, again, put your hands on the sides of the foam and compress, what happens? Draw what you see.

> Cross-Sectonal View

Names of Basic Geologic Structures

For this section, you are going to make very simple drawings of real structures. Use the computers and go to wikipedia.com. Look up the following: normal fault, reverse fault, right and left lateral strike-slip faults, anticline, and syncline. Draw each of these in the boxes provided. In each drawing, show fat arrows indicating the direction of stress that created the structure you are drawing.
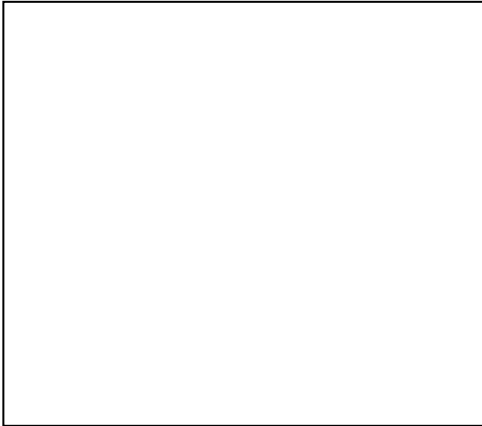
Normal Fault
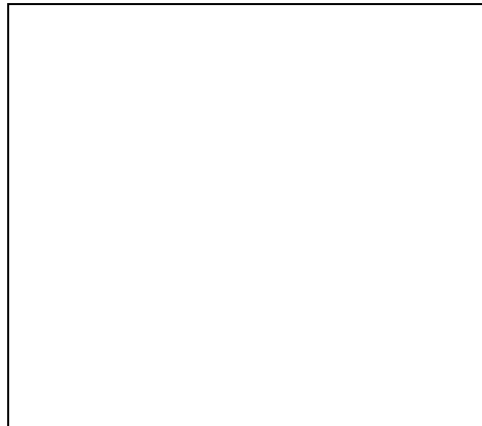
Reverse Fault

Left-lateral Strike Slip Fault
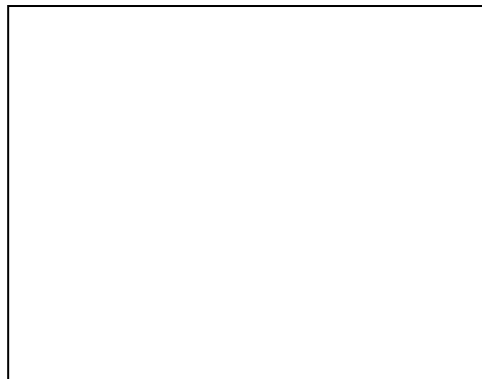
Right Lateral Strike Slip Fault
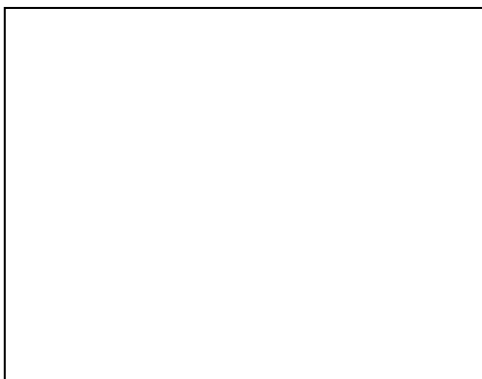
Anticline

Syncline

GeoScene

and measure the strike and dip
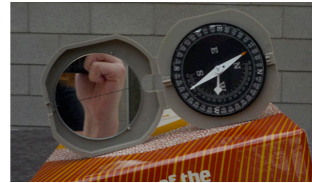
of the *white limestone* in the places indicated by on the map drawing below.
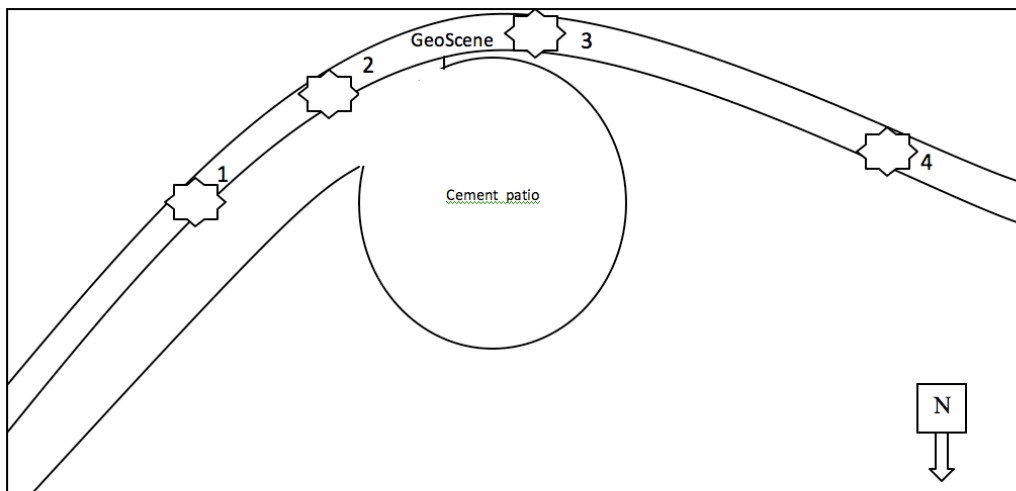
What is the name of the structure is represented between the strike and dip symbols 1 and 2?

What is the name of the structure is represented between the strike and dip symbols 2 and 3?

Though the rocks at symbol 4 are flat lying, what is the name of the structure represented?

How are all three of these structures related? How are they different?

Go back and look at the structure created by the strike and dip measured in the classroom (with the foam stands). What is the name of this structure?

Metacognition and Reflection:

1. Rate your understanding of Strike and Dip (Using a 1-10 scale, with 1 being "I don't understand at all" and 10 being "I have a perfect understanding.)

        b. Justify your rating.

2. How well do you think you can measure a strike and dip with a compass?

        b. What do you think could be done in order to improve your ability?

        c. What part of the process gives you the most trouble?

      3. Do you think the GeoScene activity (previous page) helped you in your understanding? Why or why not?

APPENDIX C

PRE/POST SURVEY INSTRUMENT

Part 1. **INSTRUCTIONS:** In this part of the survey, you are to:

1. Study how the first object in the top line of the question is rotated;
2. Imagine what the second object looks like when rotated in exactly the same manner;
3. Select from among the five drawings A, B, C, D, and E given in the bottom line of the question the one that looks like the object rotated in the correct position.
4. Circle the letter of your choice. There is only one correct answer for each question.

IS TO   AS   IS TO

A   B   C   D   E

In this example, you can see that the first object on the left is rotated 90° around a vertical axis to obtain the new configuration. Performing the same rotation on the second object yields the new configuration shown on the right. This is choice D in the sample answers.

D
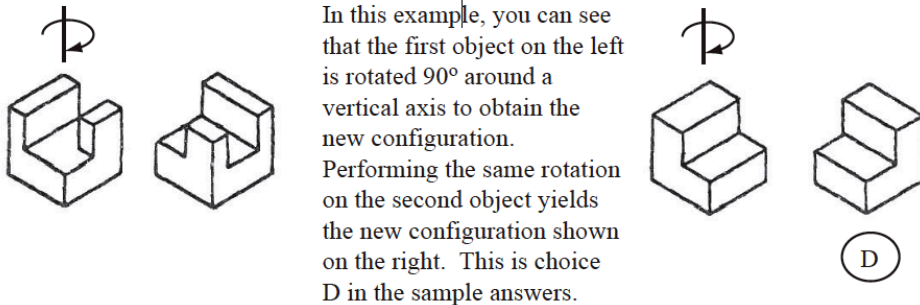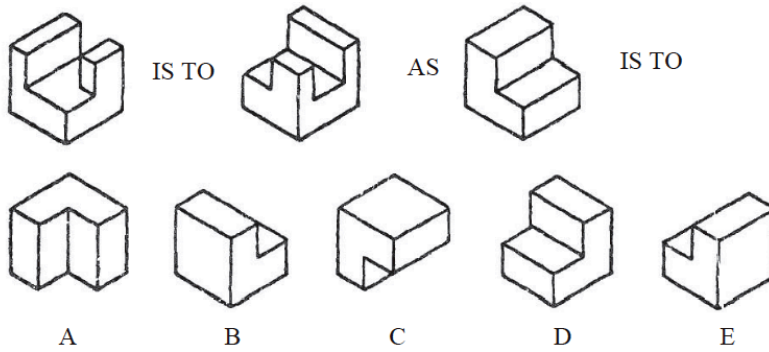
NOTE: The first object that is rotated will be the same for all questions although the rotations may be more complex than the example above. There are **10 questions** in this section. You have **3 minutes** for this section.

10.
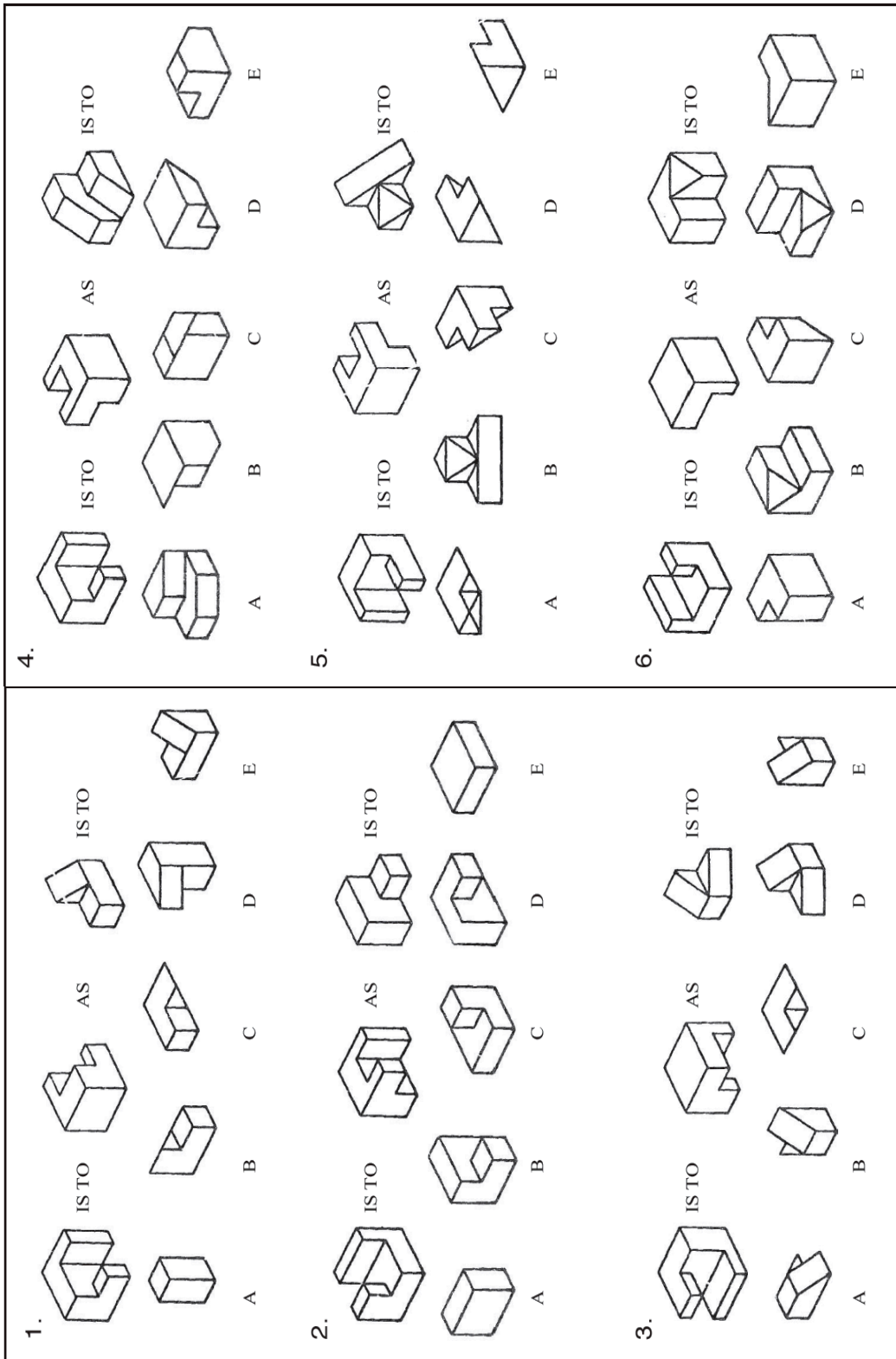
IS TO ___ AS ___ IS TO

A   B   C   D   E

PLEASE RATE YOUR CONFIDENCE YOUR ANSWERS
TO THIS SECTION BY CIRCLING A NUMBER:

1   2   3   4   5

very low   very high
confidence   confidence

7.

IS TO ___ AS ___ IS TO

A   B   C   D   E

8.

IS TO ___ AS ___ IS TO

A   B   C   D   E

9.

IS TO ___ AS ___ IS TO

A   B   C   D   E

108

Part 2. **INSTRUCTIONS**: Answer the following questions related to concepts taught in Historical Geology Laboratory (GLG104)
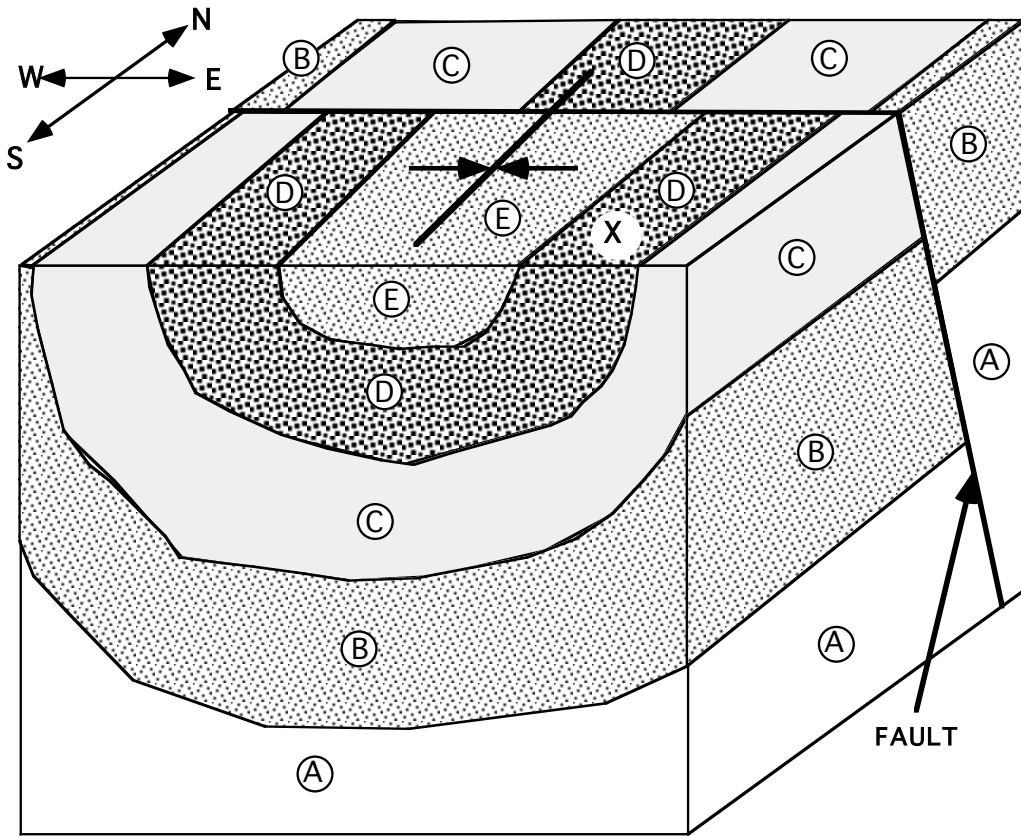
The block diagram above is of a structural feature that has been faulted, and then eroded to level. There has been NO sideways motion along the fault plane, only vertical displacement. The rock units A-E are all sedimentary rocks.

11. What is the name of the structural feature that is displayed by the folded rock in the above diagram?

12. The axis (hinge line) of this fold **strikes** in which direction?

13. The strike of the fault trace (on the top) is striking in which direction?

14. Unit D at point "X" **dips** in which direction?

15. What is the name of fault is shown?

Instructions: Using the samples provided, identify the following **mineral** specimens.

16. _____ Identify the specimen. (Mineral name)

17. _____ Identify the specimen. (Mineral name)

18. _____ Identify the specimen. (Mineral name)

19. _____ Identify the specimen. (Mineral name)

20. _____ Identify the specimen. (Mineral name)

Instructions: Using the samples provided, identify the following **rock** specimens.

21. _____ Identify the specimen. (Rock name)

22. _____ Identify the specimen. (Rock name)

23. _____ Identify the specimen. (Rock name)

24. _____ Identify the specimen. (Rock name)

25. _____ Identify the specimen. (Rock name)

Instructions: Using the diagram below, answer the questions that follow.
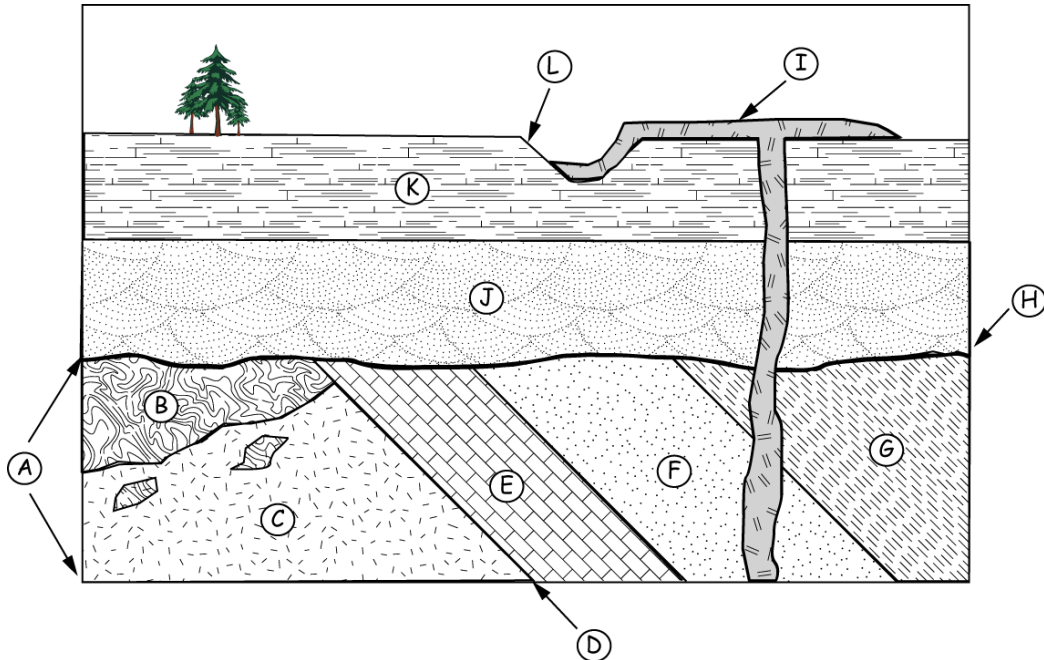
Units E, F, G, J, & K are sedimentary rock bodies. B is a schist. C and I are Igneous. A is the structural tilting. D and H are unconformities. L is the canyon cutting. Sequence the above cross section into the proper order of occurrence.

YOUNGEST _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

OLDEST _____

Instructions: Using the diagram below, answer the questions that follow.
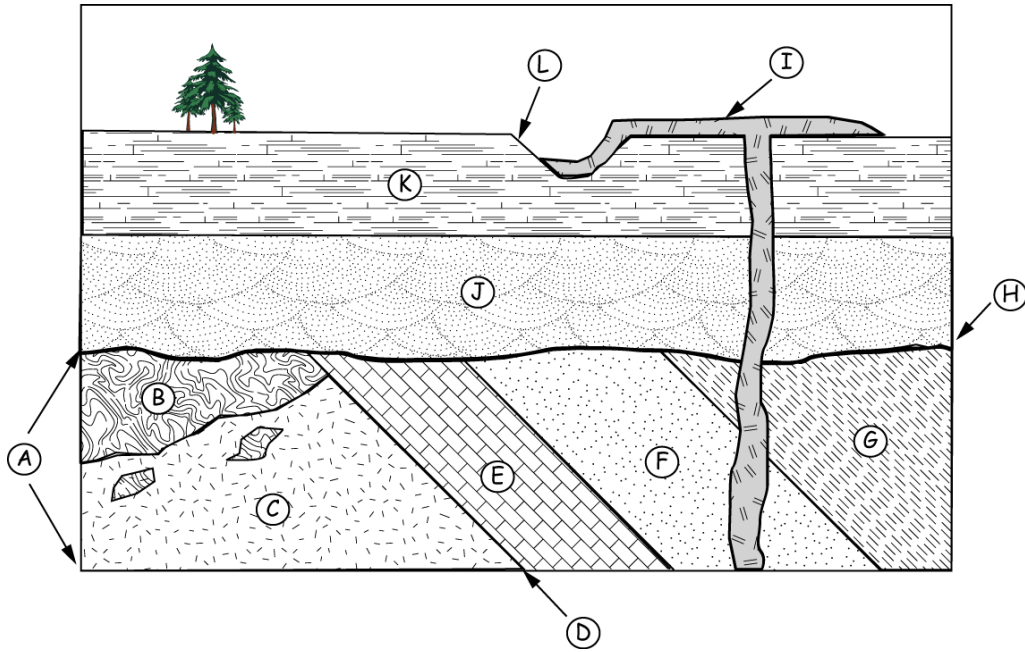
In the diagram above, determine a potential sedimentary environment for each of the rocks E, F, G, and J if:

26. E = limestone _____

27. F = sandstone _____

28. G = shale _____

29. J = sandstone (with crossbedding)
_____

30. Given the position of the rocks, please give a single environment where rocks E, F, and G could all be deposited. Please **explain** your answer.

_____

_____

_____

Part 4. **INSTRUCTIONS:** Please rate how strongly you agree or disagree with each of the following statements by placing a check mark in the appropriate box.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Compared with other students in this class, I expect to do well.					
I'm certain I can understand the ideas taught in this course.					
I expect to do very well in this class.					
Compared with others in this class, I think I'm a good student.					
I am sure I can do an excellent job on the problems and tasks assigned for this class					
I think I will receive a good grade in this class.					
My study skills are excellent compared with others in this class.					
Compared with other students in this class I think I know a great deal about the subject.					
I know that I will be able to learn the material for this class.					
I like spending time in the outdoors.					
I have a lot of experience in the outdoors.					
Compared with other students, I spent a lot of time in the outdoors growing up.					
I know how to prepare adequately for a field trip outside in the local environment.					
I am intimidated with environments that I am not familiar with.					
I know how to prepare adequately for a field trip outside in the local environment.					

Demographic Information:

Age: _____

Race: _____

Gender: _____

List all high school or college level geology coursework previously taken:

_____

What is your major? _____

APPENDIX D

FIELD PRACTICAL EXAMINATIONS

Participant #:

Lab 7: Curry Road – 10 points

Notice the grading seal has changed
It is important that I try to understand what
YOU KNOW (not what your lab partner may
know). Therefore, I will give points for honesty
(you did it yourself) and effort (you tried) versus
correctness (it is all right) and completeness (every
blank is filled).

WOW!!

Hones

Participation

Neat

Effort

Prepared

INSTRUCTIONS: Please rate how strongly you agree or disagree with each of
the following statements by placing a check mark in the appropriate box.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I can accurately measure strike and dip with a compass.					
I can identify rocks studied in class.					
I can identify minerals studied in class.					
I understand the time relationships between rocks (which is older, which is younger).					
I can accurately link sedimentary rocks to their environments					
I understand the geologic relationships between different rock types.					
I think I understand the concepts taught in this lab.					
I feel comfortable in this field environment.					
I am excited to be on a field trip.					

For this lab we will be traveling to Middle Papago Park on Curry Road. There are two parts to this lab. The first part we deal with the rocks in the roadcut (rocks exposed due to carving out the road). Here we will identify the rock types and structures and relate them. In the second part of the lab, we will construct a stratigraphic column based on the rocks we saw at Curry Road and relate them to rocks found at Tempe Butte (just across the river). From this, we will theorize what types of rocks we might find deposited further to the north.

Part 1: Roadcut at Curry Road

1. Map. Where are we? Find us on the map on the last page.

2. Observe the deposits at the Curry Road stop. Describe and identify at least 2 types of rocks on the western side of the roadcut. What sort of environment(s) are associated with these deposits

	Description	Rock Type	Potential Environments
Type 1			
Type 2			

3. On the western end of the roadcut there is a large fossil exposed (I will show you). Sketch it below.

    a. What kind of fossil is it? What does it look like?

    b. Does it represent a marine or land environment?

    c. How do you know?

4. There are other small fossils present (I will point them out).
    a. What type of fossils are they?

b. What do they imply about the environment?

5. These rocks are tilted. Take a strike and dip and record it below using the SYMBOL and WORDS.

6. Many faults are seen on the roadcut. You can see that the sedimentary layers no longer match up as they cross these faults. Sketch one of these faults and place arrows to indicate the relative sense of motion (which side went up and which side went down?)

a. What type of stress (force) would cause a fault like this?

b. What kind of fault is this?

7. Estimate the amount of offset of the fault you sketched. Discuss any difficulties below.

8. Describe and identify at least 2 types of rocks on the eastern end of the roadcut. What type of environment(s) are associated with these deposits?

	Description	Rock Type	Potential Environments
Type 1			

Type 2			

9. One of these rocks has large pieces within it. What rock type are the pieces?

10. These rocks are tilted. Measure the Strike and Dip of these rocks and record it below in WORDS and SYMBOL.

11. On this outcrop, which rocks are older, the eastern or western side? How do you know?

12. Given the color of these rocks, what type of environment is implied?

13. Given all these rocks were originally deposited in the same place, can you determine a single environment where you might find all of them?

14. Write a short paragraph describing the geologic history (what events happened to deposit these rocks and eventually have them exposed this way?)

Part 2. For the second part of the lab, we will walk to the archeological site located up the hill toward the Salt River. From here we can see Papago Park to the north and Tempe Butte to the south. These deposits have been highly disturbed by more recent tectonic activity, but at one time there may have been a complete section or stack of these rocks. One way to compile all this information is to create a stratigraphic column. Using the descriptions of the rocks I give you, create a stratiagraphic column for Tempe Butte. Create a stratigraphic column of the rocks exposed at Curry Road based on your observations. Correlate them with the rocks at Tempe Butte. Theorize what type of rocks might be found at Papago Park to the north. Correlate all the columns.

Papago Park	Curry Road	Tempe Butte

Participant #:

Lab 8: Papago Park – 10 points

Notice the grading seal has changed
It is important that I try to understand
what YOU KNOW (not what your lab partner
may know). Therefore, I will give points for
honesty (you did it yourself) and effort (you
tried) versus correctness (it is all right) and
completeness (every blank is filled).

WOW!!

Honest   Participation   Neat

Effort   Prepared

 INSTRUCTIONS: Please rate how strongly you agree or disagree with each of
the following statements by placing a check mark in the appropriate box.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I can accurately measure strike and dip with a compass.					
I can identify rocks studied in class.					
I can identify minerals studied in class.					
I understand the time relationships between rocks (which is older, which is younger).					
I can accurately link sedimentary rocks to their environments					
I understand the geologic relationships between different rock types.					
I think I understand the concepts taught in this lab.					
I feel comfortable in this field environment.					
I am excited to be on a field trip.					

Stop 1: Ramadas, Hole-in-the-Rock, Papago Park, Phoenix

1. Pick up a handful of gravel. Describe and Identify at least 2 minerals you see.

	Description	Mineral Name
Min 1		
Min 2		

2. What does the shape of the grains imply about travel distance of individual clasts?

3. What is a potential source of the clasts?

Stop 2: Top of the Hole-in-the-Rock Trail

4. Where are we? Find yourself on the map. Label where you are with a small number "1"

5. Sketch a 1meter by 1meter portion of the butte in the space below.

1 Meter

1 Meter
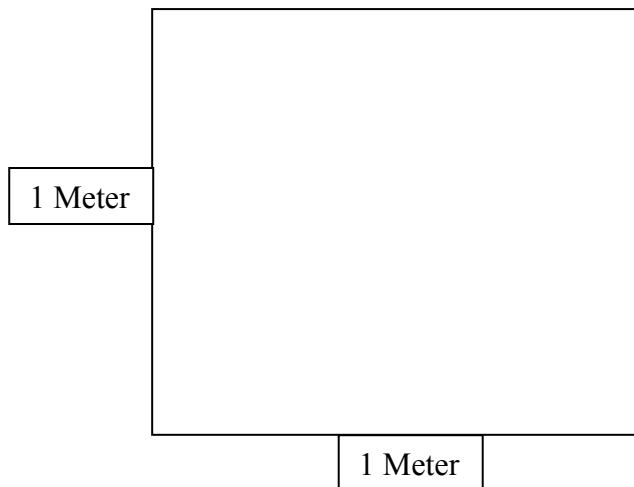
6. What type of rock composes the majority of this butte?

7. What environment does this rock form in?

Stop 3: The large butte to the North of Hole-in-the-rock

8. What type of rock is this?

9. What does the rock type imply about the conditions necessary for formation?

10. Find yourself on the map. Label where you are with a small number "2".

11. Rock "1" is 17 million years old, and Rock "2" is 1.6 billion years old. What does this imply about the contact between these 2 units?

12. Somewhere between where you are and Hole-in-the-rock is the contact between these layers. Find it, follow it until it disappears, and draw it in on your map.

13. Measure the Strike and Dip of these rocks and record it below in WORDS and SYMBOL.

Stop 4: Other interesting features

14. What type of geologic structure is present? What does it imply about the geologic history of the area?

15. Sketch the small cave along the trail on the way back from the butte. How did this form?

16. Suggest an order of the history of this area using these key processes.
    a. erosion
    b. lithification
    c. igneous intrusion
    d. erosion
    e. tilting and uplift
    f. deposition

Write a paragraph summarizing the geologic history of the area. Include a statement about what was most interesting to you.

APPENDIX E

GRADING RUBRICS FOR FIELD PRACTICAL ASSESSMENTS

Field Practical Assessment 1

Question 2	4	3	2	1	0
Rock ID (L3)	2 correct	1 correct and 1 correct mineral	1 correct rock	no correct rocks, 1 correct mineral	None correct
	4	3	2	1	0
Sedimentary Environment (L5)	2 correct environments	1 correct & 1 plausubile but incorrect environment	2 plausible but incorrect environments	1 plausible environment	None plausible or correct

Question 3			2	1	0
Fossils (L6)			Correct or Plausible		Incorrect
			2	1	0
Sedimentary Environment (L5)			Land		Marine
			2	1	0
Reasoning (L6)			Uniformitarianism		None or Incorrect

Question 4			2	1	0
Fossils (L6)			Correct or Plausible		Incorrect
			2	1	0
Reasoning (L6)			Correct or Plausible		None or Incorrect

Question 5			2	1	0
Strike (L4)			Correctly drawn and worded	Correctly drawn OR worded	Incorrect
			2	1	0
Dip (L4)			Correctly drawn and worded	Correctly drawn OR worded	Incorrect

Question 6			2	1	0

Fault Drawing (L4)			Correctly Drawn and Labeled	Correctly drawn but labeled incorrectly	None correct
			2	1	0
Stress (L4)			Correct	Incorrect, but correct in relation to drawing	Incorrect
			2	1	0
Type (L4)			Correct	Incorrect, but correct in relation to drawing	Incorrect

Question 8	4	3	2	1	0
Rock ID (L3)	2 correct	1 correct and 1 correct mineral	1 correct rock	no correct rocks, 1 correct mineral	None correct

Question 9			2	1	0
Rock ID (L3)			Correct rock	Incorrect rock but correct mineral present	Incorrect

Question 10			2	1	0
Strike (L4)			Correctly drawn and worded	Correctly drawn OR worded	Incorrect
			2	1	0
Dip (L4)			Correctly drawn and worded	Correctly drawn OR worded	Incorrect

Question 11	4	3	2	1	0
Age (L6)	Correct and sound reasoning		Either correct or sound reasoning		Niether

Question 12			2	1	0
Sedimentary Environment (L5)			Correct or Plausible		Incorrect

Question 13			2	1	0
Sedimentary Environment (L5)			Correct or Plausible		Incorrect

Field Practical Assessment 2

Question 1	4	3	2	1	0
(L4)	Identified 2 correct minerals	ID 1 correct mineral and 1 correct rock	ID 1 correct mineral	Did not ID any correct minerals but 1 correct rock	Did not ID any correct minerals or rocks

Question 2			2	1	0
(L5)			angular	specified shape but incorrect	no shape specified

Question 6			2	1	0
(L5)			Breccia	Incorrect but sedimentary	Incorrect and not sedimentary

Question 7			2	1	0
(L5)			alluvial fan	river	Incorrect

Question 8			2	1	0
(L4)			Granite	Incorrect but igneous	Incorrect

Question 9			2	1	0
(L4)			Intrusive below ground	The correct process linked with wrong ID (8)	No processes listed

Question 11	4	3	2	1	0
(L6)			Unconformity	Correct relationship, but wrong name	No processes listed

Question 13	4	3	2	1	0
(L3)	All correctly drawn and worded	Strike and dip correct drawing incorrect	Strike or dip correct drawing correct	Strike or dip correct drawing incorrect	Incorrect

Question 14			2	1	0
(L3)			Fault/PT	Fault or process but not both	Neither fault nor process

Question 15			2	1	0
(L3)			Weathering (associated w/ cracks)	Weathering (no proccess)	Incorrect

Question 16	4	3	2	1	0
(L6)	proper sequence	1 incorrect	2 incorrect	3 incorrect	Entirely wrong

APPENDIX F

INTERVIEW PROTOCOL

I just want you to know that this interview is confidential, I am the only person that will be listening to the audio, and then only for transcription purposes. All identifiable characteristics will be removed and pseudonyms will be used.

1. What made you decide to take Historical Geology?

2. Is the course what you expected? Are you enjoying it?

3. So, as you know, I'm interested in the field trips. Can you tell me a little about what you thought about the field trips in general?

4. How do you think you performed on the field trips? Do you think you did ok or did you struggle?

5. Thinking back to the Labs for a second…What did you think of the Field Core Labs (3-6)? Do you think they prepared you to go out to the field, why are why not?

What aspect of the labs prepared you or what was lacking?

So, there's a lot of information in these labs, I'm just wondering what stuck with you? What do you remember most?

What was the most helpful and what was most difficult?

What challenges did the field environment present that you didn't expect? Or was it exactly as you'd pictured it?

If you had it to do over again, what would you spend more time looking at in lab to prepare yourself for the field?

Specifically about the GeoScene. What did you think of it as a part of the lab?

Was it helpful for your understanding of the lab material?

Do you think it helped you in the lab? If so, how?

Do you think it helped you in the field? If so, how?

Do you have a lot of experience outdoors? Would you say you felt comfortable on the field trip?

Reveal