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EXPLORATORY QUALITATIVE CASE STUDY OF LAB-TYPE ACTIVITY INTERACTIONS IN AN ONLINE GRADUATE GEOSCIENCE COURSE

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ABSTRACT

This exploratory qualitative case study investigated the use of lab-type activities in an online graduate geoscience course. Constructivism is the theoretical framework used to explain how learning happens in lab-type activity, and provided the goals to which successful learning in lab-type activity is compared. This study focused on the learner-instructor, learner-learner, and perceptions of the learner-content interactions that occurred related to lab-type activities in an online graduate geoscience course to determine: if the instructor appeared as a facilitator of the learning process in the interactions over the activities; if students engaged in discussion and reflection about the activities; if students perceived the activities as meaningful and authentic; and if students perceived using higher order thinking and prior knowledge while interacting with the content.

Ten graduate students from three offerings of the course participated in this study, as well as the instructor and designer of the course content and lab-type activities. Data were collected through interviews, and observation and analysis of the lab-type activities, instructor feedback to students in their graded activities, and discussion that occurred between the instructor and students and among students about the lab-type activities in discussion forums.

The nature of the instructor's interactions in discussion forums, in feedback to students on graded activities, and reported by students' in interviews supported that, in the learner-instructor interactions, the instructor of this course was a facilitator who guided and scaffolded the students towards successfully completing the activities.

Students engaged in discussion and reflected on the activities, but most learner-learner interactions in discussion forums about the lab-type activities appeared to occur for the purpose of comparison of results, support, and empathy. Students' success at higher order thinking type questions in lab-type activities and their perceptions reported in interviews of using higher order thinking in their interactions with the lab-type activities supported that the learner-content interactions involved higher order thinking. Students also reported finding the activities realistic, meaningful and authentic, and this increased their interest with the activities, and the activities aided their understanding of the content.

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Chapter 1

INTRODUCTION

The Need for the Study

Science remains an underrepresented discipline in distance education despite the increased demand for distance education courses at the higher education level (Sloan Consortium, 2010). The lack of science distance courses is due to the nature of scientific content. That is, the culture of science is based on experimentation and evidence is at the heart of laboratory components of science courses (Kennepohl, 2009). Traditional science labs are hands-on, and require that the students manipulate, control, analyze, and/or observe a scientific process or scientific phenomena. These hands-on manipulations are often considered to be impossible to include in a distance course, thereby making the lab component the “most challenging part to deliver effectively at a distance" (p. 122). This has produced skepticism as to whether similarly rigorous lab activities delivered via traditional face-to-face science education can be effectively included into a distance science course. For this reason, many science teachers and higher educators lack the confidence that science can be taught through distance education.

Along with low number of examples of science lab activities implemented in distance courses, there is also a paucity of research into lab-type learning in distance courses, and literature that exists is often published in widely scattered educational and scientific journals (Moore, 2010). Of the scientific disciplines represented in the science distance education literature, the geosciences and Earth sciences are, by far, the least represented (Kennepohl & Shaw, 2010). This is somewhat surprising because the geosciences have many current examples of distance delivery, and, they may be better suited to distance delivery that other traditional sciences. First, the geosciences involve variations in spatial and temporal scales such that direct observation of many of the phenomena in the geosciences is not possible, and instead, relies on visualizations, animations and simulations (Cheek, 2010). In *Blueprint for Change: Report from the National Conference on the Revolution in Earth and Space Science Education*, Barstow and Geary (2001) state that with current and emerging technology increasingly available on the Internet, such as Web-mediated remote sensing and data visualizations, the use of technology can allow for greater visualization that helps students to see the un-seeable. Second, through the open accessibility of this technology, there is greater opportunity to undertake investigations on certain geosciences topics, possibly more so than in traditional classrooms. The accessibility and potential use of real data and real world authentic problems can encourage the application of knowledge making information more meaningful, and encouraging systems-wide understanding. They further stress that the use of these resources and the "dynamic pedagogical approaches that support authentic student investigations and the development of skills of inquiry, exploration and discovery" promotes the valuable approach of teaching geoscience as a process rather than memorization of facts (p. 33). Lazarowitz and Tamir (1994) also stress the importance of having students engage directly with materials and natural phenomena through data and visualization technology that have developed recently and that are opening up a new source for inquiry to students, especially for geoscience. For distance education in general, Anderson and Garrison stated that distance learners are "perhaps best positioned to take advantage of new 'virtual' learning resources in that they are generally more receptive to technologically mediated study and activities where face-to-face learning may not be a preferred or even a realistic possibility" (1998, p. 107).

Purpose of the Study

While exact reproductions of traditional lab approaches may not be possible in distance education, activities can be designed that are aimed at achieving the same goals of problem-based learning, providing students with experience in practicing science, and supporting the interaction among students and with the teacher that occurs in traditional labs. The newer technologies mentioned above are allowing for greater freedom with respect to scientific practices, increased access to scientific information available through open sources on the Internet, and technology that allows for easier interaction among students and teachers in the distance environment (Anderson, 2010). The resources are available to potentially provide effective lab-type activities in distance courses, but no studies have evaluated if lab-type activities that are designed to include the effective attributes described above can achieve these goals in online geoscience courses.

The purpose of this study was to gain insight into the use of lab-type activities in a graduate online geoscience course to explore whether the use of such can promote meaningful learning. This study focused on the use of activities that incorporate real sources of data in an online geoscience course meant to strengthen the understanding of content, and to provide students with access to and practice with scientific data. The nature of interactions and learning that occurred through the use of these activities was the focus of this study. Specifically, this exploratory qualitative case study focused on the learner-instructor, learner-learner, and students' perceptions of the learner-content interactions that occurred related to lab-type activities that use real sources of data available through open sources.

The online delivery of a geoscience course that utilized lab-type activities was an appropriate topic for my study for several reasons. Merriam (1988) states that the researcher is the primary instrument for data collection and analysis, and brings to the study his/her knowledge of the context. My background is geology: I have a bachelor's and master's degree in geology, and in my education, I gained a good understanding of geoscience topics and focused my master's thesis research on tectonics and structural geology. I have experience with geology in terms of learning it in hands-on, face-to-face labs, and the practice and application of it in fieldwork and research. I also have more than 10 years teaching experience teaching geology in both face-to-face and distance classes and labs, and experience with professional development aimed at critical and higher order thinking, and developing assessments to encourage higher order thinking. My knowledge is best applied to a study of a similar topic and context. Furthermore, the geosciences is a scientific discipline well-suited to the use of Internet-based resources, visualizations, databases, and activities, a study of which would add to the distance delivery literature for a discipline that is severely underrepresented.

Theoretical Framework

Constructivism is used as the theoretical framework to describe how learning happens. Constructivism is an epistemology of learning that assumes that knowledge is constructed in the mind as a result of how an individual makes meaning of experiences (Jonassen et al., 1995), and through the interaction with the environment (Savery &

Duffy, 1996). Knowledge creation is an active process, and the constructivist approach stresses that information that is meaningful, realistic and authentic to the learner will encourage learning. Furthermore, learning should take a student-centered approach where the teacher acts as content expert and facilitator to encourage interactions, including discussion and reflection, and presents multiple perspectives and methods. This is used as the theoretical framework because of its focus on the active construction of knowledge and active learning. Constructivism has been an influential learning theory in science education, especially the lab learning, in adult education as a design framework meant to promote meaningful learning, and similarly, as a guide to good practice in distance education (Hoskins, 2012).

Tenenbaum et al. (2001) state that constructivism's focus on active learning and active construction of knowledge requires interaction with peers, teacher and content. Sinha, Khreisat, and Sharma (2008) also state that the student-student, teacher-student, and student-content interactions described by Moore (1989) are key elements of active learning. Therefore, interactions and the nature of these interactions are a window into the presence of constructivist elements of learning in a distance course. Brooks and Brooks (1999) state "through teaching, through participating in student/teacher interactions, through observing student/student interactions, and through watching students work with ideas and materials tells us more about student learning than tests and externally developed assessment tasks" (p. 97). This comment is directed more at authentic assessment that accompanies the constructivist approach, but also seems applicable to a study of the presence of constructivist principles in a course.

Definitions of Key Terms

Several key terms that are used throughout this study and in the research questions are defined below, and described in more detail in chapter two.

Active learning. Active learning refers to students engaging in an activity with the physical and/or social environment (Roth, 1993). Active learning is an instructional approach meant to encourage cognitive activity. Bonwell and Eison state that active learning strategies are "instructional activities involving students in doing things and thinking about what they are doing" (1991, p. iii).

Authentic. Authentic activity has been defined as "ordinary practices of the culture" (Brown, Collins & Duguid, 1989, p. 34). For science learning and in this study, authentic activity refers to doing science in a manner that resembles the practice of science done by scientific communities (Hume, 2009), which includes using real phenomena, tools, and primary sources of data (Brooks & Brooks, 1999).

Distance education. Distance education is defined by Moore and Kearsley as the "planned learning that normally occurs in a different place from teaching, requiring special course design and instruction techniques, communication through various technologies, and special organizational and administrative arrangements" (2005, p. 2).

Facilitator. The teacher's role in constructivism is in contrast to the traditional teacher-centered approach where the teacher is lecturer or disseminator of knowledge. In the constructivist view, learners actively construct their knowledge, rather than passively absorbing what is provided by the teacher, therefore the teacher is viewed in this context as facilitator who employs techniques, activities and actions in order to tutor, guide and co-collaborate with the students to aid in their knowledge construction (Rovai, 2004).

The facilitator adopts an "assisting, guiding approach…to teaching" (Moore & Kearsley, 2005, p. 325).

Higher-order thinking. In this study, higher-order thinking is defined as the three highest levels in the cognitive domain of Bloom's taxonomy of educational objectives. The cognitive domain of Bloom's taxonomy classifies cognitive learning into six levels, which are, from lower-level to higher-level thinking, knowledge, comprehension, application, analysis, synthesis and evaluation. Analysis, synthesis, and evaluation are considered higher-order thinking attributes (Bloom, 1956).

Lab-type activity. Laboratory, or lab, can suggest different meanings in terms of contexts or conditions for learning. Some define lab as the physical space in which activities or experiments are carried out. But, more authors refer to lab to mean the activities that occur in lab, such as problem-solving activities or experiments in which students gain practice with the gathering, organization, analysis and evaluation of scientific data (Karagiorgi & Symeou, 2005). They have further discussed the most effective elements that typically occur during labs to make them positive learning experiences. Labs involve active and cognitive engagement with meaningful and authentic problems and tasks that require higher-order thinking (Hofstein & Lunetta, 2004; Lumpe & Oliver, 1991). Social interaction among peers and with the teacher encourages confrontation of conceptual conflicts. Labs also build on prior experiences and knowledge of the learner (Corter et al., 2007), and end with reflection (Hofstein & Lunetta, 2004). The use of "lab-type" activities in this study, then, is meant to refer to the types of activities that include these elements.

Meaningful. Meaningful is used in this study to refer to knowledge that is purposefully connected to one's existing knowledge, and that has importance, use, and fit in a larger pattern (Ausubel, 1961). Knowledge must be tied to something specific to have meaning, and ultimately, the evaluation of how meaningful an activity is depends on the learner. In this study, because the students are practicing teachers taking a course in teacher education, meaningfulness will refer to the use, utility and applicability of activity to their own practice of teaching and in their understanding of content they teach.

Misconceptions. In science learning, misconceptions or alternative conceptions refer to pre-existing conceptions of individuals that are incompatible with scientific concepts and phenomena (Posner, Strike, Hewson & Gertzog, 1982).

Online. Online can have different meanings in different contexts, but in this study and in distance education in general, online refers to distance education delivered via the Internet, as a course or program that is Web-based and may be aided by the use of a Learning Management System (Moore & Kearsley, 2005).

Reflection. Most simply, reflection refers to thinking about one's actions or thinking (Russell, 1993), but in terms of reflection over lab-type activity and in this study, it will refer to the deliberate "elaboration and application of one's learning" (Hofstein & Lunetta, 2004, p. 32).

Scaffold. Similar to facilitation, scaffolding refers to guidance provided by a more capable or more knowledgeable person (Roth, 1993). With scaffolding, an individual is able to succeed at a task or gain understanding of something that the individual would have otherwise not succeeded at without the help of the facilitator (Shiland, 1999).

Research Question and Sub-questions

The purpose of this descriptive and exploratory qualitative case study was to explore whether lab-type activities used in the online environment can support learning as described in the constructivist view. The nature of interactions are the focus of a study aimed at better understanding the use of lab-type activity in an online geoscience course through answering the following research question and sub-questions:

- To what extent does lab-type activity used in an online graduate geoscience course attain a constructivist view of learning, evident in the three types of interactions in the course?
    - Do the learner-instructor interactions represent the teacher as facilitator to scaffold learners to deeper understanding?
    - In the learner-learner interactions, do the students engage in discussion and reflection about the activities?
    - For the learner-content interactions, do the students perceive the activities as realistic, meaningful and authentic, and is there evidence of higher-order thinking in their interaction with the content? Do the activities build on the students' prior knowledge and allow for the confrontation of any misconceptions?

Methodology and Research Design

Denzin and Lincoln state that "the constructivist paradigm assumes a relativist ontology (there are multiple realities), a subjectivist epistemology (knower and respondent cocreate understandings), and a naturalistic (in the natural world) set of methodological procedures" (2000, p. 21). A study grounded in the constructivist paradigm then is suited to a qualitative methodology (Gabriel, 2004). Furthermore, a qualitative case study can be useful for discovering the meanings in phenomena and can shed light on the phenomena of active learning online. It can also explore all variables within the case that affect the phenomena of lab-type learning via distance through a holistic study, as well as possibly uncover other variables which were unanticipated. Merriam (1988) states that a qualitative case study is an appropriate approach for a situation in which "it is not possible or feasible to manipulate the potential causes of behavior, and when variables are not easily identified or are too embedded in the phenomenon to be extracted for study" (p. 7). Rather, a holistic description and analysis of the case would be useful for determining pattern of factors which are significant in the case. Overall, the phenomenon that is to be studied is well suited to the case study approach because this study fits the criteria for a case study, as the case that I studied was the bounded system of the learning that occurs through the use of lab-type activities in an online, graduate geoscience course.

To conduct a study of the constructivist approach in an online science course, I conducted a qualitative case study of the nature of interactions that occurred about lab-type activities in an online graduate geoscience course covering plate tectonics. This course utilized activities meant to involve the gathering, analysis, manipulation and evaluation of real data that is openly available through scientific organizations' and research institutions' websites. Furthermore, this course utilized interaction between the instructor and students and among students to promote discussion and reflection of the content and activities. Hannafin (1989) states that qualitative views in interaction focus more on the cognitive engagement and the purposeful processing of the content and tell more about the degree to which content has been processed by the student, the associations they make with prior knowledge, and the meaning they make from the interaction.

Data was collected through interviews, and observation and document analysis of the course design, activities and students' graded work, and discussion among students and with the instructor in asynchronous discussion forums related to the activities. Interviewing students that participated in the course provided additional insight into their perceptions of their interactions with the instructor, other students, and content, and how meaningful, authentic, and realistic they perceived the activities to be. Document analysis of their assignments was also done to further gain insight into their efforts with the content, and to support data gathered through observation and interviews. Interviewing the instructor as well provided insight into the instructor's efforts in designing the learning environment, interaction and activities. Last, a description of the course, activities and content was done to provide the readers with a better sense of the context of the case.

Assumptions and Limitations

The instructor of the course designed and developed the activities that will be the focus of study in this course, but she did not refer to them specifically as "lab-type" activities. The interpretation of these activities as lab-type activities was based on my interpretation and definition of them, through comparing them to activities from my experience that can be done in traditional labs, or to very similar activities which have the same purposes and outcomes as these activities. The instructor did agree in personal communication that the activities could be considered lab-type activities.

This study will also have the following limitations. It evaluated only one course and the activities in one online geoscience course. It was also limited by the number, characteristics and variation among the students taking the course. The number of students in the course who participated in the study totaled ten from three separate offerings of the course. These students were graduate students 25 years of age or older. They all had previous experience with distance courses, and seven with the instructor. The students were also employed in education or an education-related field.

These limitations constrain the results of the study, such that conclusions cannot be expected to relate to other populations of distance geoscience students, for example, younger, unemployed undergraduate students lacking experience with distance courses. Therefore, results cannot be generalized to a larger population, or to other cases of distance science lab-type activities. However, this is a limitation of qualitative case study research in general. The purpose is to explore the phenomenon in depth, rather than to make generalizations about the issue (Merriam, 1988).

Because three separate offerings of the course were used in this study, variations existed in the amount of time between when students finished the course and when they were interviewed, therefore, there may be limitations in terms of how well certain students recalled the course and activities. Five students were interviewed one year after completing the course, four students were interviewed several months after completing the course, and one student was interviewed one week after completing the course. Students interviewed one year after completing the course may not have remembered the activities or their interactions within the course about the activities as well as students interviewed right after they completed the course.

My role as observer as participant in the course may have also have affected the behavior of the students and the instructor. Both the students and the instructor knew that I was observing their course, and this may have altered their behavior such that it was different than it would have been if my presence was not known. However, these students were already evaluated by the instructor on the nature of their contributions and work, so the nature of interactions should not be drastically different from what it would have been without my presence.

Furthermore, the subjective nature of several aspects of this study may be a limitation. I interpreted the data in this study, and therefore it is presented based on my perceptions and interpretations, which are inherently affected by natural biases. Also, students were interviewed and asked about their interactions with aspects of the course, instructor, other students and the activities. Results are also presented based on the students' perceptions of their interactions, for example, the students' perceptions of their own assessment of their higher order thinking.

Last, the study was only slightly limited by access to the asynchronous discussion forum and to data sources within the course. Two of the seven students who took the course in summer 2012 did not participate in the study, preventing their contributions in the discussion forums and observation of the feedback on their graded activity worksheets from being included in the study. This amounted to three discussion threads and two graded worksheets for each activity that could not be used.

Significance

This study is significant because it contributes research to the sparse field of literature on whether the online environment can support active learning, lab-type activities. Furthermore, it is a significant contribution to the geosciences and distance delivery of the courses. Of the scientific disciplines, the geosciences rely most heavily on labs, hands-on activity, and fieldtrips as approaches to make content and concepts meaningful and relevant (Manduca & Kastens, 2012). If this study can show that similar activities can achieve the same goals when delivered online, it would strengthen the use of this delivery mode in geosciences education. Furthermore, few studies have focused on the use of active learning, lab-type activities in distance courses from the viewpoint of the constructivist elements they can encourage. Constructivism is at the heart of the lab-type learning, so it would follow that, with the technology and resources currently available for interaction, communication, and access to authentic sources of data openly available this could also be implemented in distance courses as well.

Chapter 2

LITERATURE REVIEW

Introduction

This chapter reviews constructivism as the theoretical framework used in this study to explain the method by which learning happens. This is followed by a review of literature pertaining to lab-type learning in science education and adult learning with respect to science, as well as science learning in distance courses. Common themes from this literature as to the effective elements of learning across the disciplines are summarized. Last, interactions in distance education are reviewed, and the chapter ends with a review of previous studies of lab-type activities in distance courses, and on the study of interactions in science distance education.

Constructivism

Constructivism is an epistemology of learning that asserts that knowledge is actively constructed in the mind as a result of how an individual makes meaning of experiences (Jonassen et al., 1995), such that understanding results from interactions with the environment (Savery & Duffy, 1996). Wheatley further elaborated that "knowledge originates in the learner's activity performed on objects. But objects do not lie around ready made in the world but are mental constructs" (1991, p. 10). These mental constructs are generated through the meaning-making process which involves the interaction of information and external reality with and through the filters of the individual's prior experiences and beliefs (Tam, 2000).

The most commonly recognized divisions in constructivism are the variations that focus on the role of either individual or social influences in learning. Cognitive or personal constructivism focuses on the individual and the individual's construction of schemas, as triggered by the individuals' interactions with the environment (Matthews, 1993). It has been criticized for the lack of emphasis it places on the role of social interactions in knowledge construction and for placing too much emphasis on the individual (O' Loughlin, 1992). But, von Glaserfeld (1993) states that even radical constructivism views social interactions between and among learners as important to the knowledge building process, they just play a secondary role to the necessary and prerequisite cognition and action that must take place internally before an individual interacts with others. Both individual and social constructivist views share the common ideas that knowledge is built in a community, individually and collectively, that social interactions in a variety of settings are important to building knowledge, that knowledge is mediated through language, and that prior knowledge and experience are essential elements (Staver, 1998).

Elements of Constructivist Learning

Constructivism is an epistemology and learning theory that describes the nature by which learning happens, more than a pedagogy or instructional design (von Glaserfeld, 1993), but it has been translated into instructional approaches that are meant to encourage learning in the constructivist view (Tenenbaum et al., 2001), which have the following characteristics or approaches:

Meaningful. Activities meant to encourage learning in the constructivist perspective are meaningful (Wilson, 1996; Honebein, 1996; Jonassen et al., 1995).

Ausubel (1961) defines meaningful learning as knowledge that is purposefully connected to one's existing knowledge rather than being arbitrary information. For meaningful learning to occur, the student must have relevant prior knowledge, the knowledge itself must have meaning, importance, use, and fit into a larger pattern, and the student must choose to learn. Ultimately, the knowledge must be tied to something specific for the student to have meaning, and the evaluation of how meaningful an activity is depends on the learner.

Authenticity. Activities should be realistic and authentic (Honebein, 1996; Karagiorgi & Symeou, 2005). The importance of authentic activity or authentic practices was stressed by Brown et al. in their discussion of the concept of cognitive apprenticeship, in which learners engage in authentic activities that they define as “the ordinary practices of the culture” (1989, p. 34). They state that participating in authentic activity adds meaningfulness and relevance of the activity, and aids in understanding. To apply this to the culture or nature of science then means that authentic scientific activity or inquiry refers to doing science in a manner that mirrors actual practice of science by scientific communities (Hume, 2009). Hofstein and Lunetta (2004) also refer to authentic scientific practice as having students "investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science" (p. 30) For authenticity in problem-based learning, problems should be tied to real life phenomena and contexts with real-life complexity, and should involve the ordinary practices and tools of the culture and professionals, including using primary sources of data (Brooks & Brooks, 1999).

Multiple perspectives and methods. Information or content should be presented via multiple perspectives and methods, and involve multiple methods for solving problems (Honebein, 1996). Constructivist learning approaches should provide multidisciplinary and holistic approaches that involve presentation and learning of information from whole to parts, rather than the traditional approach of presenting information in parts, and then expecting the student to put everything together into the whole (Brooks & Brooks, 1999).

Social interaction. Constructivist approaches utilize social interaction and collaboration between teacher and students and among students (Honebein, 1996; Jonassen et al., 1995). This interaction should involve discussion and making meaning through practicing the language of the discipline or culture (Tobin, 1998), Jonassen et al. stated that "constructivist environments engage learners in knowledge construction through collaborative activities that embed learning in a meaningful context and through reflection on what has been learned through conversation with other learners" (1995, p. 11). Reflection is a major part of the meaning making process in constructivism that can enhance understanding. Reflection most simply refers to thinking about one's actions or thinking (Russell, 1993), and involves deliberate "elaboration and application of one's learning", which can include the use of the content, the reason for the activity or parts of the activity, the applicability to other situations, etc. (Hofstein & Lunetta, 2004, p. 32).

Utilization of prior knowledge. Constructivism's view that learners construct knowledge through the filter of their prior knowledge and experiences requires that prior knowledge be utilized in learning. Students' prior knowledge has been referred to as conceptions or preconceptions. Along with the shift toward greater acceptance of the constructivist epistemology and focus on an individuals' construction of personal understanding of phenomena came a greater emphasis being placed on the role of conceptions in learning (Cobern, 1993). In science learning, individuals may come into instruction with pre-existing conceptions that may be misconceptions, naive conceptions or alternative conceptions, and which are at odds with scientific concepts and phenomena (Posner, Strike, Hewson & Gertzog, 1982). Learning science then has been viewed by Posner et al. as conceptual change, which is the process of acquiring new or alternative scientific conceptions by replacing preconceptions with scientifically valid conceptions that are incompatible with the old conceptions. Constructivist teaching involves helping students to utilize their prior understandings and reorganize them through activity in their current experience (Tam, 2000), and to evaluate rational options and thoughts and address misconceptions or alternative conceptions (Karagiorgi & Symeou, 2005).

Student-centered. Constructivist learning environments are student-centered, such that teachers act as facilitators to orient, guide and scaffold the learners through the learning process (Honebein, 1996; Wheatley 1991; Brooks & Brooks, 1999; Michael, 2006; von Glaserfeld, 1993). Constructivism's student-centered approach is in contrast to the traditional teacher-centered approaches of behaviorist learning theories, where the teacher was viewed as is lecturer or disseminator of knowledge (Rovai, 2004). Because learners actively construct their knowledge according to constructivism, rather than passively absorbing what is provided by the teacher, the teacher's role has shifted to that of tutor, guide, facilitator and co-collaborator to aid students in their knowledge construction. Roth states that scaffolding is "when an adult, an expert, or a more capable peer facilitates the performance of a student so that achievement is at a higher level than was achieved individually" (1993, p. 163). Similarly, facilitation in terms of distance education has been defined as an "assisting, guiding approach ('guide-on-the-side') to teaching" which "can be contrasted to the directive teacher-instructor ('sage-on-the-stage') approach" (Moore & Kearsley, 2005, p, 325). Scaffolding and facilitation have roots in Vygotsky's concept of the zone of proximal development, which is the difference between what an individual already knows and what the individual could know with the guidance of a more knowledgeable other (Vygotsky, 1978). More specifically, the teacher helps students to utilize prior knowledge to make preconceptions and misconceptions explicit (Hacker & Harris, 1992; Morris, 2002), and provides sufficient support and guidance through the learning or activity such that the individual invests effort, but is also able to succeed at the learning experience (Shiland, 1999).

Active Learning

A central concept of constructivism is the active construction of knowledge and learners' active participation in the learning process. This has led to pedagogical practices referred to as active learning (Osborne, 1996), within which the elements described above to promote learning in the constructivist view can be embedded. While it can be argued, according to the constructivist epistemology, that all learning must be active (von Glaserfeld, 1993), active learning as an instructional approach refers to encouraging students to engage and participate in something, rather than passively listening in a classroom. Royuk and Brooks (2003) state that, while the definition of active learning is vague, it requires some type of student performance, and Roth (1993) states that it implies learning-by-doing, hands-on activity and engagement with the physical and/or social environment. These approaches are simply used as methods that encourage an individual to be active mentally and engaged cognitively. Bonwell and Eison state that active learning strategies are “instructional activities involving students in doing things and thinking about what they are doing” (1991, p. iii). Cognitive activity promotes meaningful learning (Mayer, 2004), and through active learning approaches, students are more likely to understand and remember content (Bonwell & Sutherland, 1996; McConnell et al., 2003). Active learning can also enhance learning outcomes (Rabe-Hemp, Woollen & Humiston, 2009; Fata-Hartley, 2011), higher order thinking (Ma, 2009), and conceptual understanding (Dori & Belcher, 2005).

A broad range of approaches have been described as active learning approaches, but social interaction with or without collaboration, and problem-based learning are the two approaches discussed most in the active learning literature. Through social interaction and collaboration, students participate in discourse about the content and information, including discussing and reflecting on new information, relating it to past experiences and applying the new information (Chickering & Ehrmann, 1996; Michael, 2006). Students and the teacher question each other, which, according to Rovai (2004), is the main method for helping students to think critically and construct meaning and understanding. High levels of social interaction and collaboration can foster higher order thinking (Ma, 2009), improved academic achievement and students' attitudes and retention (Prince, 2004).

Problem-based learning often begins with a question or problem for which the answers are not known, so that the students can develop or practice approaches to solving the problem (Blumenfeld et al., 1991). Tam stresses that teachers should use “good” problems, which exemplify constructivist principles in that they require learners to use their knowledge to solve "meaningful and realistically complex" problems (2000, p. 52), and involve real phenomena (Kanter, 2010). Karagiorgi & Symeou (2005) further add that the problems should be authentic tasks and ordinary practices of a culture using the same tools as professionals in that discipline. The application of the activity to real situations or use in real situations further adds to the meaningfulness of the activity (Shiland, 1999), and Karagiorgi and Symeou (2005) state that meaningful learning occurs when students develop ways to effectively solve problems, using information given or going beyond information given, and critical thinking skills in the process (Baturay & Bay, 2010). Furthermore, good problems require holistic approaches and multiple perspectives (Rivet & Krajcik, 2008). Last, problem based learning utilizes students' prior knowledge, and in the process, can address and filter out alternative conceptions through the application of new conceptions to solve new problems (Kanter, 2010). These features of problem-based learning can increase motivation for the student (Blumenfeld et al., 1991) and engagement of the students (Ahlfeldt, Mehta, & Sellnow, 2005).

Science and Lab-Type Learning

Constructivism has been an influential theory in science education, in part, because it exemplifies "the practice and products of science" (Staver, 1998, p. 516). Many of the approaches and principles of constructivism and active learning described above have been applied in science education in a variety of ways, but they are most utilized in laboratory-type activities, and lab-type activities are examples of active learning approaches in action.

Labs are traditional elements of science education that exemplify the core component of science and provide students with practice in the application and observation of scientific concepts. Labs have been described as hands-on (Ma & Nickerson, 2006), or virtual, which include interactive computer simulations and remote access labs (Hatherly, Jordan, & Cayless, 2009), but all lab activities typically involve problem-solving, inquiry, experiments (Karagiorgi & Symeou, 2005), or discovery-based learning (Michael, 2006). Johnstone and Al-Shuaili (2001) describe different types of lab activities that range from very structured "cookbook" laboratories, to open-ended and unstructured inquiry or open inquiry labs, with discovery, guided inquiry, and problem-based labs falling in between and have varying amounts of structure and open-endedness. Open-ended, minimally or unguided labs, such as those described as pure inquiry, discovery learning, experiential learning, and inquiry learning are lab designs meant to reflect constructivist approaches (Kirschner et al., 2006). "Cookbook" labs have been frowned on for their focus on procedural knowledge and for not allowing for the negotiation of meaning and sense-making of actions that contribute to deeper understanding that are thought to accompany open-ended labs (Tobin, Tippins & Gallard, 1994). But, Kirschner et al. (2006) state that, while the epistemology of constructivism reflected in the minimally or unguided approaches is accurate, these instructional approaches actually fall short. Learners construct knowledge regardless of whether they are given partial or full information, but complete information will result in more accurate representations that are learned more easily. Minimally guided instruction places too much load on working memory, plus it can frustrate students and lead to the formation of misconceptions and unorganized knowledge (Kirschner et al., 2006; Roth, McRobbie, Lucas, & Boutonne, 1997).

Debate also exists over effective methods and approaches, but there are several agreed-on elements common to all effective labs. First, a "minds-on" emphasis is needed (Cakir, 2008, p. 202), and activities need to be well-designed, challenge the students' existing conceptions, and require higher-order thinking, such as problem-solving (Lumpe & Oliver, 1991). Second, effective labs incorporate social interaction with peers and the teacher (Corter et al., 2007). Through peer interaction, conceptual conflicts are acknowledged and dealt with, leading to accommodation of new concepts (Glasson, 1989). Interaction with the teacher and the teacher's expert knowledge can help students to refine their skills and habits, and to discard useless ones for ones that help the students to solve the problem (Wickman, 2004). Third, labs utilize the experience and prior knowledge of the learner (Corter et al., 2007), and learners can confront misconceptions in this way, as well. Fourth, effective labs involve meaningful activity and authentic problems and tasks (Hofstein & Lunetta, 2004). Fifth, the activity in labs is engaging, and this helps to make information more concrete, and helps students to make connections between normally disjointed topics (Bigler & Hanegan, 2011). Last, there must be reflection about the activity, as reflection is a major component of the minds-on aspect of labs (Hofstein & Lunetta, 2004). Bettencourt concisely sums up the attributes of effective lab activities that follow constructivist principles: learners must manipulate things for a reason and to answer some question, engage in discussion and reflection about their efforts, end with accounting of what happened, and interactions in labs among teacher and students should "focus on processes such as the assignment of language to concepts, negotiation of meaning, and arriving at consensuses" (1993, p. 81).

Geoscience Learning

According to constructivist epistemology, students assimilate information into existing knowledge structures that are based on their previous experiences. Misconceptions can form when previous knowledge and deeply ingrained mental models that apply to their everyday experiences are inappropriately applied to new concepts and phenomena that are beyond their everyday experiences (Cheek, 2010). The geosciences incorporate concepts that involve great variations in spatial and temporal scales (Piburn et al., 2002), making many of the concepts and processes impossible to observe directly, and therefore unfamiliar to most students and challenging aspects of learning in this field. For example, plate tectonics, past geologic events, and effects of long-term processes must be observed in indirect ways that rely heavily on the ability of students to visualize concepts, thereby making the geosciences one of the most visual sciences. Visualization relies heavily on spatial thinking, which is involved in prediction, observation, description, classification, explanation, communication and manipulation of two- and three-dimensional shapes, internal structures, and processes (Kastens & Ishikawa, 2006). Spatial ability is a cognitive factor that has been linked to high performance in science and mathematics, but especially the geosciences (Black, 2005; Kastens, 2010).

Much of the research on spatial ability in the geosciences has focused on individual differences, specifically, on gender differences. Several authors have concluded that males perform better at spatial tasks (Chabris et al., 2006; Black, 2005; King, 2008; Dabbs et al., 1998). However, a similar number of authors have contradicted research that oversimplifies the generalization that males are better at spatial thinking than females. Berfield et al. (1986) found that spatial ability was better in males, but could not be solely attributed to brain biological differences. Self et al. (1992) attributed the differences in spatial ability between males and females as resulting from societal and cultural causes, but found that these differences are disappearing. Socioeconomic status was even shown to play a role in spatial ability by Levine et al. (2005). Self and Golledge (1994) found that females actually performed better at some spatial tasks than males. Furthermore, research has shown that a gender gap in spatial ability could be minimized, even reversed, through practice and instruction (Black, 2005; Titus & Horsman, 2009), such that Ishikawa & Kastens (2005) caution against assuming that females are at a disadvantage in the geosciences due to poor spatial ability.

Misconceptions tend to persist for many students for topics and concepts in the geosciences due to the spatial thinking required and the unobservable nature of them. For example, misconceptions that stem from the scale complexity include those for processes and phenomena related to plate tectonics and the Earth's interior (Clark et al., 2011), time relationships and deep time (King, 2008), groundwater and the hydrologic cycle (Arthurs, 2011; Spellman et al., 2003; Sibleyet al., 2007), rock formation (Kortz & Marray, 2009), and climate change (Papadimitriou, 2004). However, the spatial nature of the geosciences cannot account for all of the common misconceptions in the geosciences. Students may reject conceptions of geologic phenomena due to deeply help personal (Libarkin et al., 2007), religious (Cervato & Frodeman, 2012), or supernatural beliefs (Tsai, 2001). Students may also hold alternative conceptions of geologic phenomena due to the influence of mass media on natural disasters (Barrow & Haskins, 1996, as cited in

Cheek, 2010; Parham et al., 2011). Other variables also affect learning of complex Earth systems, such as instructor pedagogical content knowledge and student science attitudes and motivations. Sell et al. (2006) concluded that that prior knowledge was the most important variable. They found that students with greater prior knowledge in geology were better able to practice inquiry and build conceptual models, while students with less prior knowledge had more difficulty. Because of this, Cook (2006) recommends presenting information using multiple representations, especially presenting information via dual-mode of visual and verbal, with animations and instructional guidance that accompanies visual representations.

Several other instructional approaches have been proposed to confront misconceptions and alternative conceptions. First, curricula and interventions that focus on spatial aspects of concepts can improve students' abilities and conceptual understanding (Black, 2005). For example, concrete modeling or computer animations and models can help students to visualize two dimensional phenomena in three dimensions (King, 2008), and make good visual analogies that can aid understanding (Jee et al., 2010). Activities in lab, such as interaction with models, phenomena and processes, can help with interception of misconceptions (Dal, 2009; King, 2008). Nelson et al. (2010) found that university students who participated in introductory geology labs performed significantly better in lecture and on their final grades than students who only took the lecture portion without a lab, and the largest gains were seen in nontraditional students over 25 years of age. This is also important because nonscience majors tend to have more difficulty understanding science concepts than science majors (Black, 2005).

Adult Learning

Andragogy, or the study of adult learning, provides a set of characteristics about the general adult learner, which are considered good practices for adult education, and programs for adults should be designed with these taken into consideration (Knowles et al., 1998). These characteristics are that adult learners are self-directed and invest more effort in diagnosing their own learning. Adult learners are ready to learn when the information will help them with a real-life problem, have a focus more on problem solving than learning about a subject, and learn best when new information in presented in real-life context, experiential approach. Adults are also internally motivated, and prefer to know the reason behind why they are learning something and how they will go about learning something. Last, learners have a wealth of experience to draw from, and these experiences should be utilized in learning as new information is tied to previous knowledge.

Andragogy shares many similarities with constructivism and active learning approaches. Both stress ownership of the learning process by the learner and learner-centeredness, and the importance of reason and meaningfulness in the learning activities and content. Furthermore, interactivity and sense of community are important characteristics of the adult learning environment (Merriam et al., 2007), just as they are in constructivism. Yakimovicz and Murphy (1995) further state that “the constructivist teaching model is particularly well suited for adult education in that it facilitates active development of personal meaning through the interaction of current conceptions and ongoing experiences’’ (p. 203). Both also have an emphasis on experiential learning, and Lewis and Williams conclude that experiential learning is active learning, where students are "doing things and thinking about what they are doing" (1994, p. 8), through, for example, active experimentation and problem-solving. Tenenbaum et al. (2001) even state that university students and older adults tend to prefer the constructivist learning model.

In terms of science learning, science education literature is more voluminous for primary and secondary education, but the literature that addresses adult learning of science has noted unique problems inherent in the science education of adults. First, several researchers mention low rates of scientific literacy for adults. This is a problem, especially in a time when scientific and technological advancements progress at faster rates. Added to this, adults may not prefer science and be reluctant to enroll in science education due to bad experiences with science education in primary or secondary school, and out-of-date knowledge due to a long hiatus from school (Fryshman, 1973; Hacker & Harris, 1992; Morris, 2002; Prather & Shrum, 1987). Last, Bannier states that many adults view science as a difficult subject because it is abstract and "uncomfortably positivist" (2009, p. 227), and often feel as though the course has no relevance to them. Despite these problems, Morris (2002) states that adults tend to be curious about scientific phenomena, but Prather and Shrum (1987) state that adults are also more likely to withdraw from a program that does not satisfy them.

A particular group of adults that have been the subject of much of adult science education literature are pre-service and in-service teachers that teach science at the elementary or secondary levels. Howitt (2007) found that pre-service teachers' considered science pedagogy and performing science activities, or doing the science they would teach, as the most important aspects in their confidence toward science and science teaching. However, a common theme exists in pre-service and in-service teacher science education literature, that teachers feel unprepared to, or uncomfortable with, teaching science due to having a limited background in the discipline and/or negative feelings toward it (Goodman, Freeburg, Rasmussen, & Meng, 2006). As a result, these teachers tend to have low confidence in teaching science and conducting lab activities, and tend to teach only what they are comfortable with, thereby limiting their possibilities for instruction (Nilsson & van Driel, 2011). But, Nilsson and van Driel and Goodman et al. (2006) found that content knowledge and attitudes toward teaching science can be improved for these students through labs, problem-solving activities and interactions with more-knowledgeable others and peers.

From literature about adult science learning and challenges, several suggestions for best-practices for adult science education have been made. Adult science education programs should utilize the learners' interests, needs and experiences, and be tailored to their preferences in order to make the program effective. Topics covered should be covered in depth rather than providing a breadth of coverage, and there should be an interdisciplinary approach that covers information which has practical application to the students, rather than covering a set of facts (Fryshman, 1973). Courses should take a learner-centered approach where the teacher acts as facilitator to help the students utilize their prior knowledge (Hacker & Harris, 1992; Morris, 2002), and find information in order to be lifelong learners (Prather & Shrum, 1987). The teacher should encourage discussion, intervene with concepts and examples, when appropriate, make connections among topics, and summarize information periodically (Morris, 2002). Furthermore, for lab-type learning activities, activities should include real and meaningful content, such as real materials, apparatus, experiments or situations. Labs should be practical and useful for the students, for example, exposing pre- and in-service teachers to labs that they may implement in their own teaching, giving them a chance to do and practice what they will teach. Simply providing the experience and practice in new methods of learning can also help to improve the confidence and comfort with the subject matter, techniques for teaching it, and in applications of it. And, throughout labs, interaction with a teacher and peers should be available and used extensively.

Constructivism and Distance Education

Constructivist and active learning approaches similar to those described above have been implemented in distance education (Jonassen et al., 1995), and even found, in some cases, to fit better with distance education (Tam, 2000). Developments in interactive technologies and computer mediated communication are allowing for interaction and the collaborative aspect of the constructivist approach to be used in distance education (Tenenbaum et al., 2001), and can support a constructivist learning environment through the use of them (Jonassen et al 1995, Carr-Chellman, Dyer, & Breman, 2000). Asynchronous learning networks and use of threaded discussions have been shown to allow for collaboration, knowledge construction, interactive and cooperative learning environments, sense of community, and reflection (Rovai, 2004). Rovai states that, through the use of communication tools in the online learning environment, learners are able to "(a) articulate what they know; (b) reflect on what they have learned; (c) support the internal negotiation of meaning making; (d) construct personal representations of meaning; and (e) support intentional, mindful thinking"

(2004, p. 83). Authentic, problem-based learning has also been shown to be feasible in distance education (Carr-Chellman et al., 2000), and Dixson (2010) found that students reported active learning activities, such as problem solving, discussion, labs, and projects, as well as interaction among student and with the teacher as the most engaging elements of distance courses.

With the possibilities for instructional approaches that exemplify constructivist principles in distance education, several authors have made recommendations for effective and engaging distance learning. Active learning should be incorporated into distance courses, including social interaction (Johnson & Aragon, 2003; Ke & Xie, 2009), and social presence of instructors (Dixson, 2010). Instructors should use assignments that engage students with the content of the course and with each other (Dixson, 2010). Bonk and Zhang (2006) and Johnson and Aragon (2003) suggest including what they refer to as hands-on activities in distance courses. The activities they describe are not literally hands-on, but rather activities figuratively referred to as hands-on because they involve learners in "applying what they have learned, reflected on, and visualized in practice exercises or in the real world" (Bonk & Zhang, 2006, p. 260). These are activities that use both individual and group effort, and include discovery learning, problem-based learning, and projects (Johnson & Aragon, 2003). Ke and Xie (2009) further stress that learning opportunities connect new knowledge to past experiences, stress the reason or purpose and application for the learning, and encourage self-reflection.

Active Learning in Distance Science and Geoscience Education

Activities that might be conducted in traditional science labs are examples of active learning approaches that can be utilized in distance science courses (Corter et al., 2007). Elements of lab-type activities in face-to-face courses that make them effective would also make distance lab-type activities effective. Specifically, manipulatives and lab-type activities must contribute to an evolving discourse, students must be given opportunities to ask questions, receive feedback, reflect and modify their ideas (Hofstein & Lunetta, 2004). But, conducting lab-type activities through the distance delivery mode can be challenging and result in minor differences in learning outcomes. Feedback, reflection, and interaction that are also critical to lab-type activities in distance courses may occur in different ways, and possibly more easily, in distance courses. Distance lab-type activities can allow students to work at their own pace, which can provide more time for reflection and increased cognitive process (Al-Shamali & Conners, 2010), rather than being constrained to a block of time as in traditional face-to-face labs.

Traditional hands-on labs and virtual labs have been implemented in distance science courses (Mickle and Aune, 2008) with positive results on learning from hands-on (e.g. Johnson, 2002; Casanova et al., 2006; Reuter, 2009) and virtual labs (e.g. Hatherly et al., 2009; Elliott & Kukula, 2007; Abdel-Salam, Kauffman & Crossman 2006, 2007; Corter et al., 2004). But, implementing the same practices and lab-type activities as face-to-face courses may not be possible, or even necessary. More recently, high-quality Internet resources, computer-aided learning courseware, Web 2.0 technologies and databases have been used in distance science education to provide students with authentic, real-world, lab-type, problem-solving activities that involve the use and manipulation of real data (Bannier, 2009; Scanlon, 2011). Students can experience firsthand scientific discoveries in different subject areas, and support interdisciplinary inquiries through the use of such technology (Ou & Zhang, 2006; Bonk & Zhang, 2006). For example, Ou and Zhang state that "learning with databases may be constructive and meaningful when students are actively engaged in knowledge construction by asking questions, analyzing data, seeking answers and drawing conclusions" (2006, p. 50), and working with databases can promote development of higher order thinking skills and allow for collaboration.

Online and Internet resources can also aid in visualization of concepts through the use of models and animations. Increased accessibility to publicly available resources, such as Google Earth and open-source remote sensing and imagery resources, can be used to improve the visual aspect of the geosciences and to allow for better observation of large-scale phenomena (Cloutis, 2010). Dong, Xu & Lu (2009) discuss the use of multimedia content in earth science in online courses. They state that Web-based resources can be useful for their ability to incorporate multiple methods of presenting information, such as audio, video, text, images and animations, into very visually interesting and interactive instructional materials. The use of these can, in turn, promote the interest and motivation of the learner.

Summary of Constructivism and Lab Learning

Lab learning exemplifies active learning approaches, specifically social interaction and problem-based learning that uses good problems as described above. Labs are important to science education, but may be especially useful in geoscience education where the spatial and temporal variations make learning in this discipline challenging, and best aided by practice in visualization. Lab-type learning is also useful for adult learners, who prefer problem-based approaches, and for practice in the scientific process which utilizes prior knowledge. Furthermore, the multidisciplinary approach and multiple perspectives and methods for solving problems are also recommended in the adult science learning literature. Though the nuances of how these elements can be implemented and executed in a distance course may differ slightly, research has shown that they can still be fostered in this learning environment. Through the review of literature on lab learning in science education, adult learning and adult science learning, and distance education, common themes emerge that highlight how constructivist principles permeate throughout these different areas.

Interactions in Distance Education

Interactions are a critical element of learning in the constructivist view, as it views knowledge as being created through interaction between the learner and external objects and content (Benbunan-Fich, 2002; Tenenbaum, Naidu, Jegede, and Austin, 2001), and with peers and the teacher (Sinha, Khreisat & Sharma, 2008). Constructivist learning then utilizes and encourages interactions with content, the teacher, and among students to lead to an increase in the depth of learning and understanding (Hoskins, 2012). Interactions are also critical to distance education, as Woods and Baker stated that "interaction is at the heart of the online learning experience" (2001, p. 2).

Moore (1989) first described and discussed three types of interactions that occur in distance courses: learner-content interaction, learner-instructor interaction, and learner-

learner interaction. Learner-content interaction is described as “the process of intellectually interacting with content that results in changes in the learner's understanding, the learner's perspective, or the cognitive structures of the learner's mind" (p. 2). Moore compared this to internal didactic conversation originally described by Holmberg (1983). Learner-instructor interaction involves the learner interacting with an expert on the subject matter. The instructor would have planned the content and in this interaction, the instructor seeks to stimulate and sustain students' interest, motivation and self-direction. Instructors also assess learners’ effort and results of their effort, and provide support and guidance to the students. Last, learner-learner interaction is the interaction between and among learners, as they work either individually or in group work, and with or without the involvement of the instructor.

Several authors have added to Moore’s original three types of interaction in order to provide a more comprehensive accounting of the all interactions that occur in distance education. Hillman, Willis and Gunawardena added learner-interface interaction, which they define as “a process of manipulating tools to accomplish a task" (1994, p. 34). They found that Moore’s interactions lacked consideration of the interaction students must have first with the technology required in distance education for communication with other students, the teacher and content, so learner-interface interaction is an interaction unique to distance education. This interaction can impact the learning experience because learners’ proficiency with the medium or technology affects their success in gaining the desired information and their engagement and interaction with the content and others. In order for the learners to be successful in the learner-interface interactions, learners must be able to operate the technology or interface, but also know why they are to operate the interface. Usun (2004), who refers to this interaction as learner-technology interaction, states that students must reach a comfort level with the technology in order for it to be used and useful.

Also building on Moore's three types of interactions, Anderson (2003) proposed the interaction equivalency theorem, which introduced aspects of quality and quantity to the three interactions (Miyazoe & Anderson, 2010). The interaction equivalency theorem states that:

- Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student–teacher; student-student; student-content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience
- High levels of more than one of these three modes will likely provide a more satisfying educational experience, though these experiences may not be as cost or time effective as less interactive learning sequences (Anderson, 2003, p. 3).

Studies of the Interaction Equivalency Theorem found that students' opinions of value of interaction type varies with the mode of instruction, that is, that face-to-face students valued instructor interaction, while distance learners valued content interaction (Miyazoe & Anderson, 2010). Rhode (2009) interviewed ten undergraduate distance students and found that students valued interaction with the instructor and content most, and viewed them as being equivalent, but more valuable than student interaction. Furthermore, elimination of one or two of the interactions could not produce a satisfactory learning experience. Bernard et al. (2009) confirmed the equivalency theorem, and found that increasing quantity and quality of any of the three interactions positively impacted student learning, but in a result contradictory to the results of Rhode's study, found that the student-teacher interaction had the smallest effect on student performance as compared to student-student and student-content interaction. These studies support the first theorem, but indicate that more research is needed into the second theorem (Miyazoe & Anderson, 2010).

Another important contribution stemming from the study of quality of student, teacher and content interactions is the Community of Inquiry framework (Garrison, Anderson & Archer, 2000). The Community of Inquiry framework consists of social, teaching and cognitive presences, which, at high levels, result in more effective educational presence and a purposeful community of inquiry. This framework has been an often-cited framework applied to the study of interaction in distance courses, as "quality interaction and discourse for deep and meaningful learning must consider the confluence of social, cognitive, and teaching presence—that is, interaction among ideas, students, and the teacher" (Garrison & Cleveland-Innes, 2005, p. 144). It is based on a collaborative constructivist foundation and much of the interaction is focused on collaboration. Due to the focus on a collaborative foundation of learning, the Community of Inquiry framework will not be used in this study, but useful elements of instructor, social and cognitive presence that pertain to quality of student-student, student-teacher and student-content interactions will be discussed and evaluated.

The contributions of Anderson (2003) and Garrison, Anderson and Archer (2000) stress the importance of the quality and nature of interactions. Bernard et al. (2009) stress that the number of interactions are not necessarily reflective of the amount of cognitive engagement invested into an activity, and simply having interaction in a course does not result in deep learning, either (Dennen & Wieland, 2007). Dennen and Wieland stress that students must interact with each other and with course materials at deeper levels for internalization of knowledge and interactions must foster cognitive engagement. More specifically, elements of learner-instructor interactions that promote deep learning include communication of expectations and guidelines, timely feedback, and sharing of persona and empathy (Dennen et al., 2007). More importantly, the instructor designs, structures, facilitates and leads the efforts and activities that are meant to promote learning of meaningful learning outcomes (Anderson et al., 2001). This structure and leadership by the teacher are crucial for deep and meaningful learning and higher-order, critical thinking (Garrison & Cleveland-Innes, 2005). Furthermore, the instructor encourages student-student interaction through questioning aimed at encouraging critical thinking (Marks et al., 2005). The instructor also assists the learners and acts as mediator with learning the content through a variety of methods that are best suited to the learners (Moore & Kearsley, 2005). For example, discussion threads that are clear rather than disjointed and follow progression through phases of inquiry (Garrison & Cleveland-Innes, 2005).

For learner-learner interaction, this interaction has been viewed as a way for students to discuss content (Moore & Kearsley, 2005), and to participate in negotiation of meaning and co-construction of knowledge in shared learning environments (Sringam & Greer, 2000). However, Marks et al. (2005) found that student-student interaction in small groups and peer-teaching had little influence on learning, and Garrison and Cleveland-Innes (2005) state that social presence does not encourage deep approaches to learning, but is necessary for rapport and a sense of emotional support. O'Reilly & Newton (2002) supported this with a study of students' perceptions of online discussions. They found that students valued interaction for forming friendships and gaining advice, empathy and encouragement. Rovai (2004) further added that social interaction promotes a sense of community is linked to a more satisfying learning experience for students.

Through learner-content interaction, each learner constructs “his or her own knowledge through a process of personally accommodating information into previously existing cognitive structures” (Moore & Kearsley, 2005, p. 140). For content to lead to meaningful knowledge construction, it must actively engage students (Anderson, 2003; Anderson & Garrison, 1998), however, Marks et al. (2005) caution that the nature and amount of the content affects its value, such that too much content can be overwhelming for students. They suggest that content be interacted with through problem-based approaches and exercises. Bernard et al. (2009) agree that content designed for strong interaction should be more active content. A recurring theme in, and goal of, learner-content interaction is that it encourage cognitive engagement, evidence of which has been cited as higher levels in in the cognitive domain of Bloom’s taxonomy of educational objectives, and critical thinking, which has been included with and considered indicative of higher-order thinking (e.g. Bonwell & Eison, 1991; Dennen & Wieland 2007; Garrison, Anderson & Archer, 2001; Sringam & Greer, 2000; Yuretich, 2003). The cognitive domain of Bloom’s taxonomy classifies cognitive learning into six levels, which are, from lower-level to higher-level thinking, knowledge, comprehension, application, analysis, synthesis and evaluation. Analysis, synthesis, and evaluation are considered higher-order thinking attributes (Bloom, 1956). Learner-content interaction should also involve discourse (Garrison, Anderson & Archer, 2001), and reflection about what has been done (Cross, 2003).

Last, learner-interface interaction contributes to quality of the course itself through both the quality of the technology and as a result of the students' proficiency with the interface or technology. Bray, Aoki, and Dlugosh (2008) and Cho (2011) found that students who were more competent in using the technology were more satisfied with a course, and concluded that students less proficient with a technology would encounter obstacles in learning. As technology becomes more sophisticated, it becomes more important that students are able to interact with the technology and that the technology has educational value, rather than being too cumbersome that it hinders the learning process (Usun, 2004). To increase students' comfort with more complex technology, the technology should be modeled and students given practice opportunities (Hillman et al., 1994).

Previous Studies

Science and Geoscience Distance Education

Few studies exist on distance geosciences education, some of which are descriptive accounts of the development and delivery of a course. For example, Gore (1998) provides one of the earliest cases of fully distance courses for the geosciences offered via videoconferencing through the Georgia Statewide Academic and Medical System distance learning network. This study only describes the design and execution of this course, but nothing related to evaluation or the course or elements of the course.

Most studies aim to gain insight into students' experiences. Werhner (2010) compared the performance on an exam of traditional face-to-face and online students enrolled in an Earth science course offered through a community college. Results showed no significant difference between the delivery methods. This study showed that the distance course can offer the same learning outcomes as a traditional course, but did not include use of lab-type activities. Clary and Wandersee (2010) quantitatively analyzed the results of surveys given to practicing teachers enrolled in graduate-level online course about their experience with lab-type experiences utilizing Google Earth. Students had mostly positive experiences and reported being able to use the exercises in their own classrooms, though they expressed some frustration with using the program and need for further assistance, such as modeling through recorded lectures or streaming video. Another study aimed at the use of multimedia content for geoscience in online courses was conducted by Dong et al. (2009). They evaluated the use of high-quality online instructional resources to aid in visualization of concepts for the geosciences, but also to increase the interactivity and student-centeredness. They found, through their quantitative analysis of exams and learner satisfaction surveys, that the online resources were positive elements of the course that have potential to promote deep learning. In a similar study, Schwerin et al. (2006) describe a NASA-funded program for providing online professional development for in-service Earth science teachers. The course used asynchronous threaded discussions and journals for reflection, inquiry and problem-based learning approaches. They found that the course improved the teachers' confidence about teaching the content. Gosselin et al. (2010) describe another NASA-sponsored, online graduate course for teachers, the Laboratory Earth project. This course included a multidisciplinary approach, encouraged interactions among the students and with the teacher, used activities which used everyday materials and occurrences as content to build on, field-based activities, kitchen labs, simulated experiments, and individual reading and writing. Analysis of pre- and post-course surveys showed significant gains in teachers' content knowledge, efficacy beliefs toward teaching science, and enjoyment and sense of community from the course. Through their collection of some qualitative data, they found that the teachers appreciated having content they could use in their own classes, and concluded that appropriately designed online coursework can provide effective professional development. These studies show that active learning approaches with Web-based programs, multimedia, and lab-type activities can be positive additions to distance geosciences courses, with appropriate guidance. They can also be beneficial for visualization of concepts in the geosciences and useful for teachers in their practice. But, these studies evaluate courses or elements of courses though mainly or only quantitative methods and analysis.

Qualitative approaches aimed at understanding of the lab-type activities or active learning approaches in distance courses have been conducted only in other scientific disciplines. Annetta et al. (2008) describe a graduate science distance course delivered through a virtual learning environment which involved the students in creating virtual games. Results of the qualitative surveys and observations from 13 students indicated that students had very positive attitudes toward the use of the technology and principles used in this course, and participants reported that their own students would benefit from the use of this technology and the engagement involved in it. Doiron (2009) conducted a similar qualitative case study of perceptions from the instructor and seven community college students participating in an online biology virtual lab. Students and instructor perceived that the online biology labs were positive experiences and provided successful learning opportunities, but there were problems with lack of immediate feedback from the instructor and input from other students, and four out of seven students thought the quality of learning would be better in a traditional lab. Schulman (2011) conducted a qualitative case study of the support systems in distance chemistry courses that used Web-based simulation labs. Schulman's study included nine students and two instructors, one of which was from a different institution. Schulman found that students reported feedback from instructors, the application of content in the use of the lab activities, detailed procedures for the labs and organization of the course, and other supportive websites as supportive elements. These studies employ qualitative methods aimed at better understanding students' perceptions of the lab activities or elements of the lab activities and generally report positive results through the use of them. A study which focuses particularly on the viability of authentic, problem-based learning in a distance course was conducted by Carr-Chellman et al. (2000) for a course on instructional design. The distance course was compared to the same traditional face-to-face course, and involved 28 students from the traditional class, and 23 students from the distance class. The researchers collected qualitative data through surveys (completed by 28 traditional students and 21 distance students), interviews (given by eight traditional students and 12 distance students), and observation and document analysis of students' journals. They found that authentic problem-based learning is possible in the distance environment, but requires that students have prior experience in collaborating online. This study was aimed at the use of an active learning approach, but it is not used in a science course. No studies were discovered in education literature on the qualitative study of lab-type activities in geoscience distance courses.

Interactions in Distance Courses

Several studies have focused on interactions and constructivist approaches in distance courses. Steffen (2006) evaluated if distance learning is an effective delivery mode for a constructivist-based undergraduate, science education course for pre-service science teacher education programs. Through qualitative analysis of the student-student, student-teacher, and student-material interactions, she found that students could work collaboratively, participate in sustained inquiry and authentic practices, and have scientific discourse through the use of the CMC, which also encouraged creative and critical thinking skills. She concluded that the course achieved the goal of exemplifying constructivist principles. However, Liang, Ebenezer and Yost (2009) studied the nature of interaction and communication in a WebCT Bulletin Board to evaluate the presence of inquiry-type communication in pre-service teachers' research project interactions. Qualitative analysis of the discussion showed that the pre-service teachers' communication exhibited collaborative discourse, but they failed to critically examine each other's points of view, leading the authors to conclude that development of this skill requires more guidance. These studies incorporate qualitative methods aimed at better understanding constructivist perspectives in distance science courses, but active learning or problem-solving activities that could be considered lab-type activities are not studied.

Rowe and Asbell-Clarke (2008) conducted a study of interactions in distance courses on elements that are somewhat similar to active learning or lab-type activities. The focus of this study was to evaluate online science courses for teachers in professional development to determine what characteristics of the course produced the most positive learning outcomes for the teachers. They studied 296 adult participants from 40 online science courses, and used the Community of Inquiry framework to predict that students who experienced higher levels of social, cognitive and teaching presence would report more positive science learning. Within cognitive presence, they included hands-on applications and interacting with physical things or models, as well as minds-on activities which involved "wrestling with scientific issues and developing their own understanding of scientific ideas" (p. 81). The outcomes they evaluated were final grades, mastery of science content, and quality of participation in online discussions. They conducted a qualitative analysis and results showed that high levels of course support were important to students' mastery of content and quality of participation in online discussions. High levels of instructor support correlated with higher grades but lower levels of mastery and quality of discussion, and high frequency of hands-on and minds-on activities correlated with lower grades while high frequency of "pen and paper" activities correlated with higher grades (p. 94). These results are somewhat unexpected and contradictory to the studies that report positive learning outcomes through the use of active learning approaches.

Hannafin (1989) states that qualitative study of interaction focuses more on the cognitive engagement and the purposeful processing of content, and can provide more insight into the degree to which content has been processed by the student, associations they make with prior knowledge, and meaning they make from the interaction. Several studies have focused on quality of interactions and qualitative analysis of them. Roblyer and Wiencke (2003) developed a rubric for the assessment, evaluation and encouragement of interactions in distance courses. Their rubric rates characteristics of social and rapport building design, instructional design, technology resources, and learner and instructor engagement on a scale with descriptions that constitute low to high levels. Nandi et al. (2009) also develop a comprehensive conceptual framework for evaluating the quality of interactions in online asynchronous discussion forums. They built on prior research in this area, but contributed parts that were lacking or shortcomings in previous studies to develop this comprehensive framework. They focused on both interactions between learners and instructors, and for instructors to assess the interaction among learners. Their framework also acts like a rubric for assessing the quality, from poor to excellent, in terms of content, interaction quality, and other objective measures. Similar to this, Nandi et al. (2012) conducted qualitative grounded theory case study in which they analyze online, asynchronous discussion forums posts to assess the quality of the discussion and aim to define quality interaction for students and instructors, specifically the instructor-student interactions. This study is another guideline for instructors to promote quality interaction. These studies are especially useful for their utility in qualitative analysis of student-student and student-instructor interaction in asynchronous discussion forums in distance courses.

Learner-content interaction has not received the same amount of study as learner-learner and learner-instructor interactions. In the literature for learner-content interaction, evidence of higher-order thinking as indicative of cognitive engagement and quality student-content interactions is cited often. Perkins and Murphy (2006) conducted an exploratory case study of critical thinking in online asynchronous discussions to develop a model, partially based on previous literature, for evaluating critical thinking in asynchronous, online discussions. Their model identifies clarification, assessment, inference and strategies as four categories and related processes that are indicative of engagement in critical thinking in the discussion. But, more studies specifically use Bloom's taxonomy of educational objectives for assessing higher-order thinking skills. Much of the evaluation of higher-order thinking using Bloom's taxonomy has occurred in face-to-face science courses implementing active learning approaches (e.g. Yuretich, 2003; Fata-Hartley, 2011; McConnell et al., 2003), but it has also been applied to distance courses. Notar et al. (2005) attempted to develop a model for promoting higher-order thinking in authentic, problem-based learning in distance education using Bloom's taxonomy. Alonso, Manrique and Vines (2009) conducted a study of a constructivist instructional model for an information technology course delivered both face-to-face and online. The model was designed, in part, to promote higher level knowledge in Bloom's taxonomy. Quantitative analysis of grades and surveys showed similar learning outcomes between the delivery modes. Wu, Bieber and Hiltz (2005) utilize Bloom's taxonomy in an activity in which students cooperated in the development and answering of questions for an exam using an asynchronous discussion. They found through quantitative analysis of surveys that students preferred the approach and reported that it enhanced their learning. These studies use quantitative methods to assess cognitive engagement, but cognitive engagement and higher-order think are probably better assessed qualitatively, and several studies have taken this approach. Dennen and Wieland (2007) assess higher-order thinking evident in asynchronous discussion in two online adult liberal arts courses using both Bloom's taxonomy and the Community of Inquiry framework. They found that facilitation and questioning by the instructor in the asynchronous discussion forum fostered greater amounts of deeper learning. A similar study was conducted by Zhu (2006), in which asynchronous online discussions in graduate education courses were analyzed qualitatively to assess cognitive engagement using Bloom's taxonomy. Zhu found all levels of Bloom's taxonomy evident in the discussion. This supported, in part, that much of the student-student interaction is social and supportive in nature, but that there was also evidence of higher order thinking. These qualitative approaches provide useful guidelines for the assessment of cognitive engagement evident in asynchronous discussion.

Summary of Research on Lab-type Activities in Distance Courses

Positive and effective attributes of constructivist principles and active learning approaches are evident throughout literature on science and geoscience learning through lab-type activities, for use for adult science learning and in distance courses. However, the culmination of these fields with constructivist approaches has not been studied, so there is a need for more research into the use of constructivist and active learning principles for distance geosciences courses for adult learners. Interactions are a window into the presence of constructivist elements in a course, and there is also a need for more research into the quality of interactions using qualitative approaches aimed at the study of learner-learner, leaner-instructor, and learner-content interactions.

Chapter 3

METHODOLOGY

Introduction

This chapter reviews the methodology used to explore whether the online environment and use of lab-type activities in a graduate, online geoscience course can promote learning as described in the constructivist view, and to answer the following research questions and sub-questions:

- To what extent does lab-type activity used in an online graduate geoscience course attain a constructivist view of learning, evident in the three types of interactions in the course?
    - Do the learner-instructor interactions represent the teacher as facilitator to scaffold learners to deeper understanding?
    - In the learner-learner interactions, do the students engage in discussion and reflection about the activities?
    - For the learner-content interactions, do the students perceive the activities as realistic, meaningful and authentic, and is there evidence of higher-order thinking in their interaction with the content? Do the activities build on the students' prior knowledge and allow for the confrontation of any misconceptions?

Rationale for Qualitative Research

Qualitative research involves a holistic study of a phenomenon in its real-life context (Yin, 2009). In contrast to quantitative research, which aims to study a phenomenon's component parts and attempts to minimize the effects of the extraneous variables (Gall, Gall and Borg, 2007), qualitative research focuses on how all the parts work together through a holistic description and explanation of the phenomenon (Merriam, 1988). Stake further states that "qualitative researchers have pressed for understanding the complex interrelationships among all that exists" (1995, p. 37). Cause and effect relationships are not necessarily a goal of qualitative research as they are in quantitative research, instead, multiple variables are often considered in a qualitative study and it seeks out to uncover expected as well as unanticipated relationships. Merriam (1988) supports this by stating that non-experimental or descriptive research is used when "description and explanation (rather than prediction based on cause and effect) are sought" (p. 7).

The underlying assumption of qualitative research is that "there are multiple realities" (Merriam, 1988, p. 17), rather than one objective reality, and these multiple realities are constructed as a result of "individuals interacting with their social worlds" and are reflected as individuals' perceptions of reality (p. 6). This is also similar to the constructivist epistemology. Denzin and Lincoln state that "the constructivist paradigm assumes a relativist ontology (there are multiple realities), a subjectivist epistemology (knower and respondent cocreate understandings), and a naturalistic (in the natural world) set of methodological procedures" (2000, p. 21). The goal of qualitative research, then, is to gain a better understanding of the processes by which individuals interpret their experiences and it seeks for in-depth understanding of meaning. Stake (1995) also states that qualitative research promotes experiential understanding that comes about from personal interpretation of events and phenomena. For these reasons, qualitative research is especially suited to educational and social research, and constructivist-oriented frameworks.

A qualitative case study has been referred to as "meaning in context" (Merriam, 1988, p. 19). The context, setting or situation in which individuals experience a phenomenon is also emphasized and is considered important in shaping individuals' perceptions. A case study can be defined more specifically as a holistic description of a bounded system or multiple bounded systems within which context and phenomenon under study are too closely tied together to be evaluated individually (Yin, 2009). The aim of a case study is to better understand all variables acting within this bounded system to provide a holistic view of a phenomenon (Stake, 1995). This in-depth study of variables that influence a phenomenon make a qualitative case study appropriate for when a researcher has an interest in process more than behavioral outcomes (Merriam, 1988). The holistic and descriptive nature of a case study also makes it appropriate for areas of research where there is little knowledge to provide insights into a phenomenon, which can then inform and provide a base for further research.

In contrast to quantitative research, which uses large sample sizes and the researcher has some amount of control over the variables in the study, the holistic and in-depth focus of qualitative research necessitates small sample sizes, and therefore, subjects it to scrutiny in terms of the lack of rigor in this research approach (Yin, 2009). That is, there tend to be more concerns over reliability, validity and generalizability in qualitative studies. But, even Manduca and Kastens (2012) state, in relation to rigor in quantitative applications and in the sciences, that “this is an imperfect notion of rigor. Every equation and every number has qualitative information behind it that determines its accuracy and suitability for use in a particular situation” (2012, p. 3). Furthermore, these concerns may be misapplications of constructs more applicable to and originally intended for quantitative research. For example, external validity or generalizability, that is, applicability of the results to a larger population and to predict future events, is not necessarily a goal of qualitative case studies. Qualitative case studies aim to better understand a unit of analysis, the case, and the phenomenon. Even so, Merriam (1988) states that a qualitative case study does have the potential to “examine a specific case but illuminate a general problem” (p. 13). Stake (1995) further elaborated that an instrumental case study which is linked to theoretical and practical issues can be used to “understand something else” (p. 3). And, Yin (2009) defines another construct for quality of research studies, internal validity, which seeks to establish a causal relationship. This is also not applicable to exploratory or descriptive studies. In terms of qualitative studies, Merriam (1988) better defines internal validity as how findings match reality, and the goal of a qualitative study is to provide an accurate description of the participants’ perceptions and the researcher’s interpretation of reality. Last, reliability refers to if the results can be repeated, and this is another construct more applicable to quantitative studies. For qualitative studies, Merriam (1988) suggests instead that reliability refer to if the “results make sense—they are consistent and dependable” (p. 172). There are specific techniques and practices conducted in qualitative research to ensure that the study is trustworthy and valid, and these will be described and addressed in more detail below.

Rationale for a Qualitative Case Study

Yin stated that the case study approach is most appropriate for studies "where the boundaries between phenomenon and context are not clearly evident" (2009, p. 18). This applies to this study because the context in which the content is delivered to the learners in the distance course is intricately tied to the phenomenon of applying that content in the active learning approaches. The case I studied was also a bounded system of the learning that occurs through the use of lab-type activities in an online, graduate geoscience course. By limiting the study to one case and one course, I focused on a holistic view of the interactions that occur in this course and a more in-depth study of the learning that occurred around lab-type activities. Last, an instrumental case study provides understanding of something else (Stake, 1995), and results of such a study can be useful to provide a general description and common themes which may exist for active learning activities implemented in a distance science course.

The purpose of this study was to better understand the nature of interactions that occurred over lab-type activities in an online geoscience course. That is, if the activities promoted learning through the constructivist view, evident in the learner-instructor, learner-learner, and learner-content interactions in the course. More specifically, I aimed to determine, based on my observations and interpretations, if the students perceived the activities to be meaningful and relevant, realistic and authentic; if the students used interaction with other students for support and to aid in knowledge construction; if the interaction with the teacher showed the teacher as facilitator to scaffold the students to understanding; and, if the students' interactions with the content utilized higher-order thinking. These aspects were addressed through a qualitative study of the learner-instructor, learner-learner and learners' perceptions of learner-content interactions that occurred several times throughout the course. Qualitative study of interactions can gain more insight into the engagement and meaning making process than quantitative approaches to studying interactions (Hannafin, 1989).

The Case

I studied the use of lab-type activities in an online graduate geoscience course on the topic of plate tectonics. This course was an elective course offered as part of a fully online Master of Education in Earth Sciences degree. The course was also part of an initiative to provide open courseware for online learning in the geosciences. The course was developed and is taught by an assistant professor of geosciences. The course took place over 15 weeks in the spring semesters, and 12 weeks in the summer semester.

This course was chosen because it exemplified constructivist principles, that is, there was an interdisciplinary approach and a systems, whole-to-parts approach, rather than coverage of content in small, disconnected pieces which were then translated to larger phenomena, and there was interaction among students, the instructor and with content. The instructor allowed for participation in asynchronous discussion forums. Students were given a resource for asking questions about content or the activities in a Questions discussion forum, which the instructor conceptualized as allowing for interaction as what would typically occur in weekly meetings in lab. Furthermore, Teaching and Learning Discussion forums placed in three lessons in the course were specifically aimed at teaching and learning reflection. The main reason this course was chosen was for the use of active learning with activities that resembled lab-type activities. These activities were meant to involve the search for, gathering, analysis and problem-solving of real sources of data available through online resources and databases. Through the use of these activities, it is intended that the students have a purpose and reason beyond the course for doing the activities, because they could potentially be useful in their own teaching. This use and practical application of the activities should add meaningfulness to the activities for the students.

Data Collection Procedures

Students who took the course in the summer 2012, spring and summer 2013 were contacted by e-mail and asked to participate in this study. Students who agreed to participate completed the informed consent form (Appendix A). The instructor also completed an informed consent form (Appendix B). Once I was given consent to include them in the study, I collected data using multiple sources: interviews, and observation and document analysis of the course, activities and students' graded work on the activities in the course over the summer 2012 and spring and summer 2013 offerings of the course. One student who gave consent did not provide an interview; therefore, this student was not included in the data analysis.

Interviews. Interviews are one of the most important data sources in case study research (Yin, 2009), and are necessary when "we cannot observe behavior, feelings, or how people interpret the world around them" (Merriam, 1998, p. 72). Along with this, interviews are appropriate for a study following a constructivist theoretical framework, as interviews gain insight into the personal interpretation made by each participant. Stake stated that “the interview is the main road to multiple realities” (1995, p. 64). Furthermore, interview data can yield more complete information about a phenomenon (Merriam, 1988). To ensure maximum variation and multiple perspectives about the case, Creswell (2007) suggests interviewing as many students as possible to provide a more comprehensive view of the case.

I conducted semi-structured interviews with the ten students who completed the course and the instructor. Of the 10 interviews, nine were recorded phone interviews, and one interview consisted of written responses to the interview questions, as the individual was not comfortable with doing a phone interview. Interviews occurred over the summer of 2013, so interviews of students from the summer 2012 offering occurred one year after they participated in the course, and for the spring 2013 students, a couple of months after they competed the course. The student from summer 2013 was interviewed at the end of the summer to ensure that this student had interacted with all of the activities in the course.

Semi-structured interviews use predetermined, open-ended questions. This approach ensured that each participant was asked the same set of questions, and it aimed to gain the same type of information from each person (Merriam, 1988). Creswell (2007) stated that interview questions should reflect the research question and subquestions in a more narrowed and specific manner, and use language that is easily understandable to the respondents with explanation of any unfamiliar terms. Furthermore, interview questions should be phrased to avoid multiple questions, leading questions and yes-or-no type questions (Merriam, 1988). Semi-structured interviews also allow for flexibility to ask spontaneous probing questions (Gall et al., 2007). Probing questions can provide more insight into responses that need clarification, more details, more explanation, etc. (Merriam, 1998). Interview questions asked of students and the instructor are provided in Appendix C.

I conducted telephone interviews because the participants are located at a distance and separated geographically from me and each other. Creswell (2007) stated that a telephone interview provides the best information when the interviewer does not have direct access to the respondent, but they do have the drawback of not providing the visual and informal communication of face-to-face interviews. I tape recorded the interviews and also took notes during the interview as back-up in case of equipment malfunction (Merriam, 1988).

Creswell (2007) and Merriam (1988) suggest beginning the interview by asking the respondents information about themselves or the event under study. This can help to make the respondents more at ease and willing to share information. In these beginning questions, I asked the students about their teaching experience, experience with distance education, and their familiarity with other students in the course. Merriam (1988) also suggests mentioning at the beginning of the interview motives and intentions of the researcher in the study, and reassuring that the respondents' identities will be protected through the use of pseudonyms. Creswell (2007) then suggests asking the main interview questions, which Yin (2009) states should be a guided conversation that follows the researcher's line of inquiry in an unbiased manner. The interview should end with expression of gratitude for the respondents' time and sharing, and by supplying any follow-up information, questions or procedures (Creswell, 2007).

Observation and document analysis. I played the role as observer as participant, where the individuals in the course knew that I was observing, but I did not participate in any activities in the course, rather, my primary role was to be observer to gain information. Merriam (1988) recommends certain aspects to observe in a case, which are the setting, participants, activities and interactions, frequency and duration, and any other subtle factors which are important to the phenomenon. For my study, observation data consisted of the course design, activities, tools used for communication, etc. Interview data was used in conjunction with this observation as a way to substantiate the observations, and vice versa.

Documents analyzed in this study consisted of the open course website, activity descriptions, data from students' graded activity worksheets, and discussion postings in discussion forums and threaded discussions. The main focus of analysis was on students' work on the activities, the discussion that occurred in the asynchronous discussion forums, that is, the nature of discussion that occurred over the activities, and on the assessment of higher-order thinking. Garrison, Anderson & Archer (2001) state that higher order thinking is probably best assessed through individual educational assignments, and assessment of higher-order thinking in face-to-face science courses implementing active learning approaches has been done through the application of Bloom's taxonomy of education objectives to individual assignments, such as exams, student surveys and individual interviews (Yuretich, 2004), essay questions (Fata-Hartley, 2011), and diagrams, open-ended questions, and concept maps (McConnell et al., 2003). Assessment of higher order thinking was done partly through evaluation the activities and students' success on these assignments, that is, the level of analysis, synthesis and evaluation evident in their work. Higher-order thinking has also been evaluated in distance courses through analysis of asynchronous discussion about the content, and this will also be used to corroborate and reinforce the analysis done of assignments. And, students reported in interviews their perceptions of how much higher order thinking they used in doing the activities.

Last, Stake (1995) states that "to develop *vicarious experiences* for the reader, to give them a sense of 'being there,' the physical situation should be well described" (p. 63, emphasis in original). A detailed description of the case is provided from the collection of the forms of data described above, and supplemented with detailed description of the activities. I ended data collection according to four guidelines: when sources of data were exhausted, when I reached saturation of categories in which no new insights were being revealed, when regularities appeared in the data, and when any new information revealed was too far removed from the focus of the study (Lincoln & Guba, 1985, as cited in Merriam, 1988).

Data Analysis

Data analysis occurred during the fall 2013 and spring 2014 semesters. To protect the identities of the student participants as much as possible, they were assigned random numbers and are referred to hereafter by these numbers. Numbers assigned to the student participants have no correlation to the course offering in which he or she participated, order in which they were interviewed, name or any other identifying trait or characteristic.

Interviews. The tape recorded interviews were transcribed verbatim and saved as Word documents according to each student. Each student interview document was then read several times and dissected, and responses were copied and pasted into new documents according to the interview question. Background interview questions were summarized into the descriptions for each student in chapter four, but main interview question responses were grouped according to question. Most responses to the main interview questions followed directly after asking that question, but some responses to other questions that occurred at other times in the interview were organized according to the most appropriate interview question. For example, student three stated in response to the interview question about understanding of content, main question four, that he would think about how he could adjust the material to teach it to his eight grade students. He stated “it was obviously my job to bring information into the classroom and bring it down to their level”. I moved this response to the meaningfulness question, main question five, as it pertained more appropriately to the use of the content, rather than the students’ understanding of the content. These responses sorted according to interview question were saved as a document for each interview question with the identifier of that that interview question, for example, “Main Q1 role of activities.docx”. Each interview question document was then read over several times using the technique of horizontalization (Merriam, 1998); I read the transcripts many times and looked for occurrence of significant statements, and recurring ideas that emerged for each question. The similar ideas were grouped into categories in which I described the similar notions or ideas that were either stated outright or alluded to in the students' statements. This analysis was saved in Word documents describing the interview question, and with the identifier "analysis", for example, "Main Q1 role of activities analysis.docx". The analysis was then summarized and organized into the section for interview results, in chapter four.

The instructor's interview was summarized to provide a better picture of her teaching style and philosophy. Details about her design of the course or reasons for including certain elements was added to corroborate data from students or gained from description of the activities or course.

Discussion forums. I printed all discussion forums from all three offerings of the course, and downloaded and saved them, and organized them into similar discussion forums folders, for example, "Teaching and Learning Discussion I". I read though each discussion forum in order, for example, all three "Questions" discussion forums, then all three "Teaching and Learning I" discussion forums, etc. The discussion forums that pertained to the lab-type activities, the Questions and Teaching and Learning discussions, were analyzed in detail, which is explained below. For the Meet and Greet discussion forums, I read each to provide a better picture of each student, their teaching background, experience in the program, and how well they knew other students, etc. This information was included with the information gained from the background interview questions for each student to supplement this information. The Random Thoughts and readings discussion forums were read for any evidence of discussion pertaining to any activities, but nothing was found in any of these discussions.

The Questions discussion forum in the course was not linked to any specific lesson, rather it is described on the open course website to be:

> for general questions about the course content and activities... If you have any questions about the course content or activities, at any point in the course, please post them to our *Questions?* Discussion Forum (instead of using private e-mail). That way everyone can benefit from seeing the question and the answer! I will check that discussion forum at least once per day, Monday through Friday, to respond. While you are there, feel free to post your own responses if you, too, are able to help out a classmate!

I read through the Questions discussions for each of the three offerings of the course and counted the total number of starting posts and replies, and student versus the instructor's posts. I then highlighted posts and threads that pertained to the activities, and counted these, along with the number of replies and student versus the instructor's posts. From there, I went through each thread and characterized each post in the conversation. Specifically, I: 1) noted with a highlighter all of the instructor's posts; 2) color coded a copy of Zhu's (2006) rubric for classifying higher order thinking in discussion forums (Appendix D) and, using it as my guide, color coded each comment in the discussions pertaining to the activities as to the level of higher order thinking present in it; 3) made notes of the specific activity being discussed in the margins; and 4) reviewed statements comparing them to my guide for document analysis (Appendix E) for evidence of utilization of prior knowledge, and meaningfulness and reflection. The results of this analysis were recorded in a document titled "Questions Discussion Forum Analysis" for each course offering. Once each course offering's Questions discussion forum was analyzed, I combined the analyses according to the specific activity to show the discussion that occurred about that specific activity and similarities and differences in the conversation about that activity.

The Teaching and Learning Discussions were analyzed in the same way as the Questions discussion forum, with an exception: instead of assessing the level of higher order thinking, evidence of meaningfulness and reflection were the focus. In the Teaching and Learning discussions, students are directed to reflect on the content and activities, and discuss how they might use and adapt the activities to their teaching. These discussions are graded and students are directed to participate more than once over the span of the lesson.

Document analysis of activities and students' graded work. The activity worksheets, directions and questions for each of the six lab-type activities were analyzed using the cognitive domain of Bloom's taxonomy of educational objectives. I printed all of the activity directions and worksheets, and, using a color coded version of the cognitive domain of Bloom's taxonomy, color coded each question to indicate my interpretation of the nature of higher order thinking involved with each question. This analysis was summarized into a Word document as description of the activities. I then reviewed the graded activities from each student for each of the activities. In my color coded printout of each activity, I kept a log of the feedback the instructor provided to students for each question in terms of correct/incorrect, and other comments and suggestions. For example, with my printout of the paleomagntism problem set, in which I color coded the level of higher order thinking I assessed for each question, I went through each of the ten students' graded worksheets, and noted for each specific question if a student got that question incorrect, the instructor's feedback to them, and the nature of their error or her comment. This analysis was summarized according to each activity to provide evidence of how the students performed on the activities, on each question, and their success at each question and task in a Word document for the Activities feedback.

Analysis of interactions. Synthesizing the data analyzed as described above provided evidence of the constructivist principles present in the learner-learner, learner-instructor and students' perceptions of the learner-content interactions. This involved analysis of interaction among students and with the teacher that occur mostly in discussion forums, but also be supported with data gained through interviews and analysis of students' assignments. Students' perceptions of their learner-content interaction was analyzed, because actual learner-content interactions cannot be observed or analyzed directly. Significant statements have been organized into meaning units, and common ideas among the several meaning units reflected common themes in the case. These themes have been organized into a description of what the students experienced and the context which influenced what they experienced (Merriam, 1988, 1998). From this, I described if constructivist elements of learning were encouraged through lab-type activities in this online geoscience course (Creswell, 2007).

Quality Assurance and Trustworthiness

Several elements of my study ensured that it is valid, credible and trustworthy. First, use of triangulation in the data collection, or using multiple sources of data, has added rigor and trustworthiness to the study, and strengthened the results (Creswell, 2007; Merriam, 1998, 1998). Document analysis, observation, and interview data all added support to the data collected, and all of these data sources produced a rich and thick description of the case. The thick and rich description of the phenomenon that best conveys the experience of learning through a distance active learning approach also promoted generalizability, or external validity, of the study (Creswell, 2007; Lincoln & Guba, 1986).

Several other techniques and validation strategies have ensured reliability and internal validity of my study. My detailed description of the data analysis above is to establish an audit trail, in which I described how data was collected and analyzed in sufficient detail so that another research could replicate the study (Merriam, 1998). Yin (2009) recommends developing a case study database, which consists of the collection of data in its raw form, not interpreted or analyzed, so that data can be retrieved and results substantiated, if needed. My data and iterations of analysis are saved and secure, and adequately identified so that I can retrieve my raw data. Last, in addition to the measures described above for quality assurance in a qualitative study, Yin (2009) also mentions construct validity, which is "identifying correct operational measures for the concepts being studied" (p. 40). Multiple sources of evidence promoted this. Yin also recommends establishing a chain of evidence, so that an outside reader is able to follow the same thread of information through the study.

Chapter 4

RESULTS

Introduction

This chapter presents the results of my research and data analysis for this study of the extent that the online environment and use of lab-type activities in a graduate, online geoscience course can support constructivist learning. Data gained from description of the course and the activities are summarized first, followed by descriptions of the students and the instructor. Each activity is analyzed to provide a description of the content, and my interpretations of the level and amount of higher order thinking involved in each. This is followed by a summary of the feedback students received on their work to shed light on the student-content and instructor-student interactions. Observations from the Questions and Teaching and Learning discussion forums provide further evidence of student-student and instructor-student interactions that occurred over the activities. Last, data gained from interviews with students and the instructor provided additional evidence for all interactions, and further supported the results gathered from observation and document analysis.

Description of the Course

Open Courseware Website

Content, instructional materials and activities for this online, graduate geoscience course are delivered through an open website module. The course home page begins with a welcome message and introduction to the instructor, along with an overview of the course, learning environment, content and topics, and lessons. Links to content are provided in left navigation menus. Under a "Start Here!" menu, orientation information is provided as links to information about the course structure, learning management system, technical requirements, tips for success in the course, methods of communication and directions for the "meet and greet" discussion forum. A "Resources" left navigation menu provides links to both program and course home pages, the course syllabus, ANGEL, the learning management system, the library, an academic integrity guide, and a help and search resource. A "Course Outline" left navigation menu provides links to the eight lessons.

Each lesson begins with an overview of the topic for that lesson and timeline, content and expectations for the lesson, and what is to be submitted for grading, summarized in a table. Links on each lesson page direct the students to the lesson content, and introductory text by the instructor explains the topics and leads into the reading. Often short, roughly several minutes in duration, videos are provided that supplement the content. These are usually drawings and tutorials created by the instructor and images that are intended to illustrate the concepts or procedures. Throughout the lessons, blocks that are set apart in different color from other text are intended to focus the students' attention on specific requirements, and attention-grabbing text is intended to direct students to supplemental videos and content. Assignments are described in the lesson content in a step-by-step process, and specific questions or actions that need to be taken are outlined. Assignments also contain links to grading rubrics or criteria for how the students' work will be graded. For the first three activities, questions and text are also contained in Word documents in which students are supposed to record their work. Work for later activities, except for the last, GPS (Global Positioning System) problem set, is supposed to be recorded in documents students compose from scratch. Students are required to submit work to drop boxes in ANGEL and their work is graded by the instructor according to her grading rubric for problem sets. Each lesson ends with a page of additional resources, readings and the bibliography for the content, and a final page which summarizes everything and the tasks to be completed in that lesson. Below is a description of each of the eight lessons.

Lesson 1: Pre-instructional Activities. The first lesson is a pre-instructional, orienting lesson scheduled for one week. It contains the first discussion forum, a ”Meet and Greet” discussion, that has specific questions asking students about themselves, their interests outside of school or work, their science and education background, and their interest in the course. This lesson then begins with directions to read a scientific paper available on library e-reserves, and a second discussion about this reading. This discussion is titled “L1 plate tectonics revolution” and is guided with specific questions and directions, and suggestions for students to respond if their idea has already been mentioned. Students then are asked to choose a graphing program and perform an activity creating plots, which is graded for participation only. Many lab-type activities later in the course require making plots of data, so this exposes the students to the skill in the first lesson, and gives them an opportunity to choose plotting software. Examples and explicit directions are provided for creating, saving and submitting the plots. This lesson ends with a pre-instructional quiz, accessible in the accompanying learning management system, ANGEL. The quiz has four questions about Earth’s layers, plate tectonic theory, faults and volcanoes. The purpose is for the instructor to gain feedback about the students' geoscience background. It is graded for participation, rather than accuracy, and feedback is provided about incorrect answers. There is also a Course Orientation – Course Information Quiz, which contains ten questions that ask about course due dates, how to access everything, where to get help, etc. Scoring 90% or higher on the quiz unlocks the assignment drop boxes for the course.

Lesson 2: The Giants of Science. Lesson two focuses on plate tectonics through the review of prominent scientists who have contributed to tectonics knowledge. It is scheduled for two weeks. The lesson contains informational content on the webpages of the lesson module, and the content is supplemented with several videos the instructor created to facilitate explaining the content. This lesson then requires an activity in which students are asked to research a scientist and create a webpage about the scientist. Other students are required to provide feedback on these webpages. This work is submitted on the open website in a discussion board accessible after students log into the website, and students are asked to provide their feedback to each other there, as well. This activity is meant to be practice for students in critiquing and reviewing each other's postings, which the instructor calls "Response, Reflection, and Revision". Participation is graded according to her grading rubric for online discussions.

Lesson 3: The Geodynamo. Lesson three focuses on the geodynamo and Earth' magnetic field and is scheduled for one week. Background information is supplemented with short videos of drawings and explanations about magnetism, induction and bar magnets, etc. Directions for accessing the required reading in library reserves are provided. Guiding questions, which are also the questions for discussion in the "Lesson 3: Magnetic field" discussion, are posted in the lesson site. This lesson contains the first lab-type activity, the Paleomagnetism problem set, which is described with the other lab-type activities below.

Lesson 4: Earth's Interior. Lesson four focuses on the Earth's interior and is scheduled for two weeks. The first week of this lesson begins with introductory information and explanation which leads into the reading. The first of this lesson's two lab-type activities, an optics lab, occurs in the first week, and the second, a problem set, occurs in the second week. After students complete the first activity, they are expected to read more information and content on the lesson site, which leads into the second problem set. This interim information contains more videos and explanation, and includes seismograms used in the problem set. This lesson ends with the first "Teaching and Learning I" discussion. The instructor stated that this discussion is graded and students are required to interact by responding to "at least one other posting by asking for clarification, asking a follow-up question, expanding on what has already been said, etc.". The purpose of this discussion is for students to reflect on content from lessons three and four, and, as stated on the open course website, "consider how you might adapt these materials to your own classroom or share the ways in which you already teach this material".

Lesson 5: Forensic Geology. Lesson five focuses on mineralogy, and it is scheduled for one week. It is framed in the context of forensic geology and takes a case-study type approach, that is, a case of the analysis of minerals in soil found on a body to determine where the body had been. It begins with a reading assignment, and then the activity in this lesson, which requires students to design a lesson plan for teaching minerals. The lesson plan is graded according to a rubric designed especially for the lesson plans students develop.

Lesson 6: Volcanic Eruptions. Lesson six focuses on the topic of volcanic eruptions and is scheduled for one week. The lesson begins with information on the open website, supplemented throughout with boxes containing tidbits of information, for example, a common myth related to volcanoes. A reading assignment and questions to contemplate are posted in this lesson, but no discussion is required about the reading. This lesson contains the eruptions problem set, which is divided into two parts, separated by additional information on the open course site. This lesson ends with the second Teaching and Learning discussion.

Lesson 7: Faults and Earthquakes. This lesson focuses on faults and earthquakes, and is scheduled for two weeks. It begins with a reading about an ancient archaeological claim that is tested through tectonics and occurrence of earthquakes, and a required discussion is guided with specific questions about the reading assignment. This lesson contains the last two lab-type activities, a Greek earthquake problem set and a GPS problem set. These problem sets are separated by more information on the open course site.

Lesson 8: Capstone project. The last lesson lasts one week and is mainly devoted to outlining the requirements for the capstone project, which is expected to be a lesson suitable for students covering some topic from the course. This lesson also contains the third and last Teaching and Learning discussion.

Learning Management System

A course site in the ANGEL Course Management System accompanies the open course website each semester. Only students enrolled in the course can access the course site in ANGEL. Content contained on the course site in ANGEL includes a link to the open course website, a course schedule for the specific semester, and seven folders: a “Course Orientation and Lesson 1 Quizzes” folder contains an orientation and pre-instructional assessment of prior knowledge quiz; a “Discussion Forums” folder contains nine discussion forums; a “Dropboxes” folder which contains drop boxes for submitting completed assignments in each lesson; a “Problem Set Answer Keys” folder to contain answer keys, and a “Readings” folder for readings inaccessible through the open website. Comparison of the ANGEL course sites from summer 2012, spring 2013 and summer 2013 showed no changes among these offerings in the layout of lessons page, no differences in folders or content in folders, or order of the folders and content within folder. The problem set answer keys folder did not contain any content. The only difference observed was in the “Readings” Folder, where two readings were posted in the summer 2012 offering folder, but four in each of the spring and summer 2013 offerings. This was due to a change in the accessibility of readings from library reserves, and the instructor posted the readings in the ANGEL site. This was mentioned in the Questions discussion forum in spring 2013: two students in the spring 2013 offering posted that they were having difficulty accessing the readings, and the instructor replied that the readings would be posted in the Readings folder.

Summary

Each lesson contained information about a specific topic related to plate tectonics, and a variety of activities occurred throughout the eight lessons. They included lab-type activities, and other activities, such as researching a scientist, developing a lesson plan, and completing the capstone project. Required discussions occurred in almost every lesson, and were either for the purpose of discussing readings or reflecting on previous lessons.

No changes occurred in the class from the summer 2012 to summer 2013. This is supported by the instructor; she stated, “I don't think the content is much changed across those three offerings. Sometimes I update the problem sets when there is more current data (such as a more recent earthquake or something like that) but the topics are the same” (e-mail communication, 2013, May 30). Therefore, the only differences in the course offering over this timespan were due to different students participating in the course, but all students, regardless of the offering, interacted with the same content, activities, layout, discussions, etc.

Student Participants

This section summarizes information gained through background questions that began each interview with the student participants (see Appendix C). This information is also supplemented by information students provided in the “Meet and Greet” discussion. The students’ background in education and teaching, their reason for taking the course, experience with distance courses, the instructor, and familiarity with other students and level of comfort interacting with each other is summarized below. Ages are given as of the time of the interview, in the summer of 2013.

Student One

Student one was a 25-year old female enrolled in the Master of Education in Earth Science Degree program and approximately half-way through the program. She had a Bachelor of Science Degree in Earth and Space Science and three years of full-time teaching experience at the secondary level, where she taught chemistry, Earth and space science, and physics in tenth to twelfth grade. She stated that her passion was geology and she hoped to eventually earn a Master's Degree in geology and gain experience working in the field, after which she would return to teaching.

Student one had four classes with the instructor, and previous experience with distance courses, as all of her classes for her Master's Degree in Earth Science had been distance courses. When she took this course, she recognized names of students from previous courses, but never met any of them or talked with them outside of the class. She was comfortable interacting in discussions, and stated that she would consider her participation as average or a little above average. She was interviewed approximately one year after taking this course, and she stated that she remembered most of the activities, but some more than others.

Student Two

Student two was a 33-year old female enrolled in the Master of Education in Earth Science Degree, and approximately half-way through the program. She had a Bachelor of Science degree in Environmental Studies. Her science teaching experience was mainly in informal settings, at a museum and for an environmental education center. She had experience as a classroom teacher only as a kindergarten long-term substitute, where she taught elementary science. At the time of the interview, she worked as a curriculum developer for kindergarten through eighth grade, and occasionally kindergarten through twelfth grade, science distance education.

She had taken four or five distance courses with the instructor, and was also a graduate assistant for the instructor in a research project. She did not know anyone in the course; she remembered only recognizing their names at the time from previous courses, but and at the time of the interview, did not recall anyone who was in the course. She did not talk with anyone outside of the course. She was very comfortable with, and preferred interacting, in online discussions. In the interview, she was very forthcoming and talkative about this course, her experience in the program and with the instructor. She was interviewed approximately one year after taking the course, but she recalled all of the activities, and had copies of the activities in front her as she participated in the interview.

Student Three

Student three was a 26-year old male enrolled in the Master of Education in Earth Science Degree and completed approximately 75% of the program. He had a Bachelor's Degree in Earth Science Education, and had been an eighth grade science teacher for three years when he took this course, but at the time of the interview, approximately one year later, had made a career change and went into educational sales for a company that distributed science equipment.

Student three had two previous courses with the instructor and experience with distance courses. He knew one other person in the course; he had previous courses with that person, kept in contact with him throughout and outside of the course and the two formed a friendship outside of the course. He was comfortable interacting in the discussions with others, and valued getting to know others and their styles of learning, and how they solved problems. In the interview, he was talkative and had a very positive attitude towards the course, the program and the instructor.

Student Four

Student four preferred not to do a phone interview; rather he provided his responses to the interview questions in written form. I e-mailed the interview questions to him, along with any additional explanations or important information, and he returned the interview question document with written responses, approximately one paragraph for each question. This interview took place several months after he had completed this course.

Student four was a 27-year old male in his last semester of a Master's Degree in Professional and Secondary Education with a teaching certification in Earth Science from a different institution. He had a Bachelor of Arts Degree in Geology. He was taking this course because his current institution did not offer graduate level science courses for his degree, and he wanted to take a geology course again while also fulfilling the requirements for his degree. He had two years teaching experience as a substitute teacher, but no full-time teaching experience.

Student four took two distance courses from the institution offering this course, and this course was his first course with the instructor. He did not know anyone else in the course but was comfortable interacting with others in the course. He stated that, at the time he took the course, that he was frustrated with his current graduate program, and "was simply in a get the right answer and move on and forget about it mode". But, his self-reported attitude of investing minimal effort did not appear obvious in this course; his participation in discussions and performance on activities was comparable to the other students who were enrolled in the Master of Education program. He also stated "I felt good enough about taking the two courses online through the [institution] that if I had to take more courses and could not find an appropriate program close to where I live, I would complete the program".

Student Five

Student five was a 37-year old male who recently graduated from the Master of Education in Earth Science program, and was taking this course for continuing credits and because he was interested in geoscience. He had an undergraduate degree in environmental science, and 13 years teaching experience, teaching various science classes in public schools.

Student five had at least three previous courses with the instructor and experience with distance courses. He was interviewed several months after he completed this course. He did not recall knowing anyone in the course, but felt comfortable interacting with others in the discussion forums, and he did recall the activities. In his interview, he was not very talkative, and his responses were terse, and included a few short, "I don't remember" responses.

Student Six

Student six was a 57-year old female in her first semester of the Master of Education in Earth Science Degree. She was taking the course because she had an interest in seismology, and because her students had an interest in plate tectonics. She had a Bachelor's Degree in Earth Science and Physics, and five years full-time teaching experience teaching Earth science to ninth grade, and physical science to eleventh and twelfth grade.

Student six was taking her first course with the instructor. She did not know the other student in the course, but had experience with several distance and hybrid courses from another teacher education program, and was comfortable interacting in the discussions and online environment. She stated, though, that she was a little uncomfortable putting everything in writing and that she liked the discussion boards the least. She understood the necessity of the discussions, but preferred to have discussion in a classroom setting. She was in the last week of this course when she was interviewed. The activities were fresh in her mind, and she was talkative and forthcoming with sharing her thoughts about the course and activities.

Student Seven

Student seven was a 46-year old female approximately half-way through the Master of Education in Earth Science Degree. She had ten years teaching experience as a long-term substitute, and then as a seventh and eighth grade science and physical science teacher. She quit her full-time teaching position when she had her child, and had been a teaching assistant for an online undergraduate earth science course for the last six or seven years.

Student seven had two classes with the instructor and experience in distance education, both as a student and as a teaching assistant. She knew one other student in the course, as she had a class with her the semester before. She felt comfortable enough interacting with other students, even students she did not know previously, that she would seek support and help from them outside of the course about other classes. At the time of the interview, she still communicated with one individual who helped her with a meteorology course. In the interview with her, which occurred several months after she completed this course, she was very positive and talkative about her experience and interactions with the instructor. She mentioned how the instructor worked with her when she was dealing with problems, and she stated “I would take every class with her if I could”.

Student Eight

Student eight was a 32-year old female who had just started the Master of Education in Earth Science Degree and this course was her first class. She had a Bachelor of Science degree in Meteorology, and no teaching experience, but planned to start teaching at the elementary level once she was finished her education.

Student eight had no previous courses with the instructor, and this course was the second distance course she had ever taken; her first being a GIS course five or six years earlier. She did not know anyone in the course, but felt comfortable interacting with others in the course. She was interviewed several months after completing this course, but recalled the activities.

Student Nine

Student nine was a 40-year old male who was half-way through the Master of Education in Earth Science Degree. He had Bachelor’s Degrees in both Earth Science Education and Geology. He had six years of teaching experience at the middle school level in Earth, physical and life sciences. .

Student nine had experience with several distance courses and had taken three courses with the instructor. He knew one other student in this course, and had formed a friendship with this person over being in courses together. He was comfortable interacting with others in the discussion, and liked this method of delivery for the convenience of it. He was interviewed approximately one year after completing this course, but had good recollection of the activities, especially the optics lab. Student nine was very enthusiastic and talkative, and thought very highly of the instructor and her courses, which he stated were "all awesome, by the way".

Student Ten

Student ten was a 27-year-old female nearing the end of the Master of Education in Earth Science Degree. She had a Bachelor's Degree in Earth Science and Secondary Education, and six years teaching experience teaching physical and Earth science for eighth and ninth grade. She was taking this course because she was interested in Earth's processes, especially earthquakes and volcanoes.

Student ten had experience with distance education, and had taken three courses with the instructor. She did not know anyone else in the course, but was comfortable interacting with others in the course. She was interviewed approximately one year after taking this course, but had good recollection of the activities.

Summary

Of the ten students, seven students were at some stage in the Master of Education in Earth Science Degree, and one student had just completed the program. Ages varied from 25 to 57 and there were six women, and four men. All students had educational backgrounds in some scientific discipline or science education. Teaching experience varied among the students; six students had three or more years of teaching experience and six students were teaching at the time of the interviews. Of those not teaching full-time, one student was not teaching at all and the other four students consisted of a substitute teacher, a part-time teaching assistant, a curriculum developer, and a regional account manager for educational sales.

All students had experience with distance courses prior to taking this course, though one person had experience with only one distance course several years earlier. Seven students had taken a course from the instructor before. In terms of students' familiarity with each other, the majority of students did not know each other prior to taking this course, but three students recognized names of other students from previous courses. Two women communicated via e-mail outside and after the course, and only two men were friends outside of the course.

Instructor Information

The instructor described her teaching philosophy and purpose of this course on the open website. She stated:

> Whenever possible, I tried to incorporate a multidisciplinary study as part of the reading assignment for a particular lesson so that you could appreciate the degree of interconnectivity among different scientific subfields. I also used publicly available datasets because I hoped that, if you found any of the analyses interesting, you could easily co-opt them for your own use. If the only thing you take away from this course is a feeling of empowerment concerning your ability to go out, find an available

> dataset on the Web, and teach students to make some interesting observations from it, then I'll call that a success! The "teaching and learning" discussions were intended to get you to think about how you might use some of this material if you wanted to turn around and teach it.

When asked in the interview with the instructor, she stated that she viewed her role as the instructor of the course as the provider of the framework for the content and the resources for data, and as a guide for finding and collecting data. The data she used in the course is openly accessible data from primary sources, for example, from real-time instruments monitoring plate movement. The instructor's goal was to develop students' skills at presenting this data in ways that best convey the information. To facilitate this, she provided feedback through the course that helped the students with observing, interpreting and understanding data. She also aimed to familiarize students with the resources and using the resources to gather data, not just for use in the course, but at later times after completing the course. She stated on the open course website that she hoped "anybody who works through my classes will end up with an appreciation of those things, and hopefully learn something on the way", and will "simultaneously become familiar with the content as well as the practice of science".

Description and Analysis of the Lab-type Activities

The instructor's rationale and description of these activities is best stated in her syllabus:

> You will learn the appropriate state-of-the-art scientific content relevant to each topic by performing basic data analysis (e.g., collection,

> interpretation, and assessment) using publicly available data to complete the activities in each lesson. I have specifically designed the lessons with publicly available datasets because I want you to be able to use the data and lessons from this course in any courses you teach.

The instructor elaborated more in her interview, when asked why she included these activities in this course, by stating that she includes the activities for what I interpreted to be the interaction and cognitive engagement they promote. She said:

> I just find that I don't learn things very well myself if I just read about them, and so a lot of times, the relationship between two variables or the reason that you can follow a chain of inference and realize that all these observations lead to this hypothesis or this model probably being the right one, I personally, I can't grasp those things unless I work with the data and think about it, so I sort of try to provide that same experience for the students, dealing with a mix of both concrete and abstract.

Below is a description of each of the lab-type activities that were the focus of analysis. Layout, design and questions within each activity were analyzed according to the cognitive domain of Bloom's taxonomy of educational objectives.

Paleomagnetism Problem Set

In lesson three, students are directed to encounter the first lab-type activity, a paleomagnetism problem set. Students are expected to download a worksheet from the open website and save it so they can work though problems and answer questions within it. The worksheet is five pages and divided into seven parts. Part one of the worksheet contains three questions which, to complete successfully, require calculations of magnetic inclination using a formula and plugging values into the equation. This formula is used in several problems for calculating inclination, and then in problems where inclination is given and students must calculate latitude. Part two involves three more calculation questions, but with more emphasis on relating the calculations to real contexts and scenarios. For example, a question states, "you are at a site in India whose coordinates are 23.3° N, 75.8° E studying some basalt outcrops and your magnetometer tells you that the magnetic inclination of the basalt is 30°". Students then are expected to calculate the latitude at the time basalt erupted. With this information, students should determine the distance continents moved to their present-day locations. These types of questions in parts one and two, requiring calculations, I interpreted as reflective of application in the cognitive domain of Bloom's Taxonomy.

Parts three through five contain two to four questions each, and successful completion of them requires applying the calculations and information to diagrams. Part six contains two questions asking analysis type questions, for example, "how you can deduce the relative speeds of the spreading rates of the different mid-ocean ridges from this figure?" I interpreted that this type of question requires breaking the information in the figure down into parts from previous questions. The last part, part seven, contains two questions which are conceptual and successful completion of them requires synthesis of the information, for example, "where is the oldest ocean crust?", and making predictions and generalizations from the information and previous conclusions.

In this activity, the questions progress from application type questions to higher order thinking synthesis questions, and the problems progress from simple calculations to more complex conceptual questions which require applying previous information.

Successful completion of later questions requires extrapolating information, synthesizing previous information in different ways, and making predictions.

Optics Lab

Lesson four contains two lab-type activities, the first of which is the optics lab. The directions and materials needed are explained and illustrated with detailed and sequential pictures so that students should be able to replicate the procedure with their own materials at home. This activity involves using containers filled with water to illustrate how light is refracted through water. Students are asked to draw the ray path of light on a large piece of paper, and then measure the angles of incidence and refraction. The instructor refers to this as a lab activity, and this activity is most similar to a traditional lab activity that might be done in a face-to-face lab.

The activity worksheet is two pages and contains ten questions. Successful completion of questions one through seven involves calculating and recording data over multiple trials in tables, and plotting data on the large piece of paper on which the lab is set up. Question eight requires the analysis of possible errors in students' work. Question nine involves synthesis and prediction from data gathered in previous steps in the question "what is the largest angle of refraction (of light through water) theoretically possible and why?". The last question is a statement to students to paste a photo of their lab set up.

Snell's Law and Travel Time Curve Problem Set

The Snell's law problem set requires the translation of the concepts from the optics lab into refraction through different media, and then as seismic waves as they pass through different layers in the Earth. Successful completion of questions one through five involves calculating angles of refraction still using air and water, but now including glass into their analysis of refraction. The problem set uses layers with different velocities and more complex scenarios, for example, "now suppose you have a ray of light that passes through the three following layers: air - water - crown glass ($n_{crown\ glass}$ = 1.52)". Successful completion of later questions requires students to make generalizations and predict how light behaves as it passes between layers of varying velocities. This analysis is then supposed to be translated into scenarios involving seismic waves, and making predictions based on the previous observations and drawing the refraction of a ray path of a seismic wave through the Earth. Question six asks for the analysis of a statement, "Which words make this a true sentence? 'When a ray of light passes from a fast/slow material, the ray is bent towards/away from the normal.'" The last question describes a scenario of a ray path from a seismic wave, and successful completion of it requires predicting how this seismic wave, in the form of a sketch, would refract through different layers of increasing velocity.

Part two of this problem set continues with the worksheet from the Snell's law part. This activity involves interpreting 23 seismograms and using first arrival times of p-waves from seismograms to construct time travel curves. From this, students should calculate distance to the epicenter of an earthquake, and then answer questions about the data. Students are asked to construct drawings of inferences for how the data would be different in different scenarios. This activity involves analysis of data that substantiates the refraction of seismic waves through the Earth, the focus of the first part of this activity. This activity also first introduces data available from an open resource. The seismograms are ready-made for the students to interpret, but the instructor stated on the open course website, “if you are interested in how I produced these plots, I made an appendix page to this lesson where you can see exactly what I did. If you ever do want to construct your own exercise like this one using different data, but you get stuck, feel free to contact me, or the folks at IRIS, for help!”.

In part two of the Snell’s Law/travel time curve problem set, the questions follow a nearly similar progression from lower to higher order thinking skills required for successful completion. Question one requires knowledge and successful completion of it requires labeling of p-wave arrivals in seismograms. Questions two and three involve application and calculations. In question four, students are asked to make a plot of their calculations, successful completion of which requires comprehension of the previous data. Question five requires analysis of proximity of the stations from their data, and question six requires that students critique the pattern in their data. Question six states, “this event was large enough that it was recorded by stations even farther away than the farthest station you worked with. Why didn't I make you pick P waves for farther away stations?”. Successful completion of question seven requires synthesis of the previous procedures to obtain two seismographs of the students’ choosing and plotting this data on a new plot. The last question requires that students evaluate the plot, and critique and compare it to an assumed known.

Eruptions Problem Set

In lesson six, students are directed to complete an eruptions problem set. No worksheet is provided, and now students are required to gather data from an open resource and report it without the guidance of a worksheet. There are two parts to this problem set. For the first part, students are required to go to the Global Volcanism

Program website (http://www.volcano.si.edu/), find information about specific volcanoes on this site, and compare the sizes of the eruptions in plots to visualize the data. There are guiding steps, but it is intended that students make a problem-based synthesis of information, and create plots of the data. These plots are not prescribed by the instructor, rather this decision-making is meant to be the responsibility of the student. The instructor states in the activity:

> make these comparisons in whatever way allows you to organize and interpret the data best. Specifically, I want you to make a plot because a plot is the best way to visualize a dataset. I am going to leave it up to you to create the kind of plot that makes the most sense to you and conveys the information in the best way

This involves synthesis of information from different volcanoes, the presentation of the data in a plot, and the generation of the plot by the student requires evaluation of the most appropriate methods and design to convey the information. This task is followed by knowledge and comprehension type questions, in which students are asked to recall and describe information from their plot, intended to exercise their skills at interpreting their own plot, and test the use of their plot. One follow-up question asks, “where does the 1980 eruption of Mt. St Helens rank among all the eruptions in this activity? How about the 79 AD Vesuvius eruption? Are you surprised by these results?” I interpret these questions as evaluative type questions deliberately aimed at addressing students’ prior knowledge and pre-conceptions about the size of these eruptions. These eruptions tend to be more popular eruptions, so the instructor forces the students to place these eruptions in context of other, less well-known eruptions. This also addresses a misconception, if the students previously thought that these were some of the largest eruptions in history. The last question involves a synthesis of the data and describing the pattern evident in the plot to make generalizations about the correlation between the volcano and explosivity index.

The second part of this problem set begins with asking students to read a paper about eruptive activity at Kilauea, and then questions require students to visualize instruments and make predictions about how these instruments operate. The instructor also posted some hypothetical scenarios, from which, students are asked to make predictions. Questions that follow this first part are meant to check for comprehension of the material. The third question requires interpretation of a figure in the reading to check for comprehension of the information. Magma flow rate is also supposed to be calculated based on data in a figure in the reading, but successful completion of this question requires that the students make judgments about how to interpret the data, to do the calculation and present the result. In part two, students are directed to use the Volcanoes Exploration Program: Puʻu ʻŌʻō (VEPP), which provides information on real-time volcano-monitoring. The VEPP site is openly available, but permission is required first by contacting the site administrator for log-in information. The problem set is aimed at allowing students to gain an understanding of the instruments used to monitor a volcano and how the instruments provide comprehensive information about the volcano. It begins with reading of background information for the open resource the students will be expected to use. Part two of this problem set requires using the VALVE3 software, which allows for interaction with instrument data. The instructor mentioned that this data is not interpreted for educational use, and requires the students manipulate it to make sense of it. Students are directed to go through the data to find the GPS, tilt and Real-time Seismic-Amplitude Measurement (RSAM) data from an eruption in March, 2011, and make three plots of the data. Questions that follow this task involve analysis of the data and plots, breaking down the data and explaining it in smaller parts. For example, "lead me through the time series of the eruption as recorded by the instruments (i.e., Which instrument records the signal first? Then what happens, are there any simultaneous excursions from "normal background" recorded by different instruments? How long does the whole thing last? How did you determine when it was 'over?')". Successfully answering the second question requires synthesis of the data and relating data to the bigger picture, for example, "describe what you think is happening physically to the volcano over the course of the eruption based on the instrument record." Students then are asked to evaluate and confirm their predictions with video from a webcam that recorded the eruption event, or critique possible reasons for discrepancies.

Greek Earthquake Problem Set

Lesson seven contains two activities, the first of which is the Greek earthquake problem set. It involves working with and manipulating data openly available on the United States Geological Survey (USGS) website, making plots of past earthquakes, and questions about whether the data fit a law that predicts aftershocks. The instructor provided screencasts and written directions for how to access the data.

Part one of the problem set requires finding data about a specific earthquake. Several questions progress from a testing comprehension type questions ("What was the location of this earthquake (latitude, longitude, depth)?"), to an application and analysis type question, and then comparing the sense of movement of the earthquake to one described in a reading. In parts two and three, students are asked to observe the aftershocks of earthquakes, first from the same earthquake in part one, and then from the Tohoku, Japan earthquake of 2011. Successful completion of questions in these parts require comprehension, then progress to analysis in requiring students to find the largest aftershock and considering if it is consistent with the law that describes aftershocks. Last, in each part, students are asked to synthesize their data into plots. From these plots, they are asked to compare their data to another law that explains aftershocks, and discuss their findings. Part three contains an additional question the successful completion of which involves evaluation of the two earthquakes. The question states:

> compare the aftershock sequence for this event to the one you observed for the Greek earthquake. Does this sequence merely look exaggerated (because the mainshock was so much bigger) but otherwise the same or are there other significant differences? What I am driving at is for you to try to decide whether you can corroborate the general notion that aftershock sequences are scale independent. I know we are only comparing two sequences instead of a statistically meaningful number, but it is still worth thinking about.

This requires critiquing the plots of each earthquake and evaluating whether the differences are significant, or simply a result of scale differences. The last part of this problem set requires the students to follow similar steps, but for an earthquake they choose. The instructor states, “the point of this part of the problem set is for you to learn how you can adapt the catalog search features offered by the USGS for your own use.” This involves using the previous parts, but in a new scenario, and requires synthesis of the previous procedures. Questions following this last task are comprehension-type questions, appearing to test the success of their efforts.

GPS Problem Set

The last lab-type activity in lesson seven, meant to be done in the second week of this two-week lesson, and in the course, is the GPS problem set, which uses UNAVCO's website and the plate boundary observatory for calculation of GPS data about plate movement. The activity is slightly different because it is not described in detail in the website; rather it is laid out in a .pdf document which students must download. The GPS data is directly from UNAVCO's website. Students are asked to use the data to make inferences about plate movement, regional deformation and slip along plate boundaries. There are three parts to the worksheet. Part one involves sketching hypothetical GPS data. Successful completion of these questions requires that students make predictions of what they would expect to see for GPS monuments moving in certain directions.

Part two contains directions for navigating the website and finding and analyzing the GPS data. Comprehension type questions in this part seem aimed at checking if students are getting the correct information and where they are on track. Generally, the first seven questions are comprehension type questions. Questions eight and nine require calculations and application. The following several questions ask for analysis of distinct parts of the data and comparison of two stations. Question 12 requires evaluation of a scenario and speculation on possible reasons for differences in rates. The next question requires taking this information, synthesizing it, and making a prediction of movement 500 years in the future. Successful completion of the last several questions requires the same calculations and analysis for four more stations. An analysis question follows this group and involves contrasting the velocities of all six locations. Question 17 then requires synthesizing this information and making a generalization and prediction: "using these six stations, where you would place the location of the plate boundary / the San Andreas fault?". Questions following this require evaluation, and consideration of other types of data to substantiate the prediction students are supposed to make in question 17.

The last part of the worksheet investigates an earthquake visible in the GPS data, and calculation of recurrence interval from this data. Students first are directed to answer comprehension and application type questions, involving calculation of slip in the fault from plots in the worksheet. Successful completion of questions three and four in this part require synthesis of information. They appear as knowledge type questions and description, "describe how the P500 GPS station's position changed during the earthquake", but I interpreted them to be synthesis type questions because data from three graphs must be synthesized in order to answer the questions. This section of questions ends with an evaluation type question, in which students must search for information about this earthquake event using other sources, and either confirm the previous conclusions they should have gotten, or explain the discrepancies they might have observed. The worksheet ends with several questions about recurrence interval. Two calculation type questions lead into a question involving synthesis – an idealized calculation that requires the students to make a prediction based on a particular scenario, which is if the fault is locked. The last question, and of this worksheet, is an evaluation type question, successful completion of which indicates that the students evaluated their work and considered other methods for determining recurrence interval.

Summary

Based on analysis of the lab-type activities, I interpreted that within each activity, there is a progression from lower order thinking type questions, to higher order thinking type questions, and also a greater amount of higher order thinking type questions in later activities. All activities up to the optics lab end with at least synthesis of information, and making generalizations and predictions. After the optics lab, the activities end with evaluation type questions that intend for the students to critique their work. Later activities also begin with higher order thinking type questions, so that more complex and sophisticated tasks are asked of the students from the beginning. Other patterns are evident in the activities through the semester. There is a switch from guided worksheets provided with questions, to no worksheets provided, with the exception of the GPS problem set at the end. Presenting the information generally becomes the students' responsibility towards the end of the course, and invokes higher order thinking in the generation and synthesis of data into a method for presenting it. Last, there is a progression from data given to the students, in the paleomagnetism problem set, to introducing the students to an open resource but with data already analyzed in the Travel Time Curve Problem Set, to requiring students to go to an open resource and gather their own data and interpret it in the eruptions problem set, to using multiple open data sources in the Greek earthquake, and GPS problem sets.

Students' Success on the Activities from Feedback

This section summarizes the students' success with the activities by analyzing the grading and feedback from the instructor in their graded activity worksheets. The instructor graded all activities out of 100, so points deducted from each student on his or her worksheets are also equivalent to percentages deducted for incorrect responses. Most written feedback provided by the instructor was to point out and correct mistakes, as summarized below, but the vast majority of responses in the graded activity worksheets were correct.

Paleomagnetism problem set. For the paleomagnetism problem set, grades ranged from 77% to 100% on all ten students' assignments, with the average grade being 91.7%. Twenty-nine errors noted in the students' graded worksheets and marked incorrect by the instructor were for calculations in application-type questions. For example, in part one, eight of the ten students received feedback that their answers were incorrect for the first question, due to missing that latitude or inclination are negative in the southern hemisphere. In part two, question three, seven people received feedback that their answers were incorrect for errors in converting percent error into possible error in distances. For the rest of the application type questions involving calculations, one or two people lost points in some parts, but the majority of questions were assessed correct by the instructor for all students.

For analysis type questions, only a few students received feedback that they made mistakes. In part six, question one, one person received feedback for an error: it appears that student seven missed that this was a conceptual question and answered instead with a calculation. For question two, student eight gave a one-word answer to a question asking for a more detailed explanation. And, in part seven, question one, it appears that student four oversimplified a generalization. All other students answered these questions correctly.

The instructor also provided feedback for parts that did not necessarily require point deductions. For example, she commented to students if they were using unconventional units in expressing plate movement, such as kilometers per millennia should be expressed more appropriately as centimeters per year. She mentioned to student one to describe amount of oceanic crust exposed laterally as “width” rather than “thickness”, which suggests a vertical depth. And, to student nine, she provided feedback for how to explain his answer in more simple terms.

Optics lab. On the optics lab, grades on the ten students’ worksheets ranged from 80-99%, with an average of 92.2%. Four or five students received feedback for errors on two calculation type questions, questions two and seven. For question eight, and analysis type question, one student received feedback for an incorrect answer, asking additional questions and offering scenarios to consider. Most students appeared to do the calculations and plotting correctly, and they discussed sources of error for question eight, but for question nine, a synthesis type question, six people had feedback with corrections for errors in calculations in the formula, due to switching incident and refraction angles, or student seven appeared to estimate, rather than calculate, the answer. One student appeared to make an error that caused the instructor to provide feedback with the equation showing all steps.

Snell’s law, travel time curve problem set. Only nine graded worksheets existed for this activity. Grades ranged from 62-100%, with an average of 84.3%. The instructor’s feedback indicated that a total of ten errors in this problem set were also due to calculations. In part one, one or two students received feedback for errors on the application type questions involving calculations. On question six, an analysis type question, three students received feedback for what appeared to be an error where they switched the concepts of toward versus away from the normal. And, for question seven, a synthesis type question, two students received feedback for errors with their predictions.

For part two, question four, an application type question, one student received feedback for an error plotting, and one student received feedback for an error made due to his self-reported frustration with Excel and plotting software. For questions five through nine, which increased in level of higher order thinking required, from analysis to synthesis and evaluation, four or fewer students received feedback for errors, or the errors appeared to be due to missing the concept of the p-wave shadow zone, or for errors with calculations. In question eight, a synthesis type question, student one made note in her worksheet that she perceived she made an error, and instead, answered based on what she thought the answer should be, rather than what her data was showing. The instructor included feedback which appeared to speculate on the cause of the error, and she included her plots. It is my interpretation in this situation that student one was evaluating her work, through which she noticed that her calculations were not making sense.

Eruptions problem set. Grades on the ten eruptions problem set worksheets ranged from 87-100%, with the average being 94.2%. The VALVE software was not working for the summer 2012 offering, so the students in this offering did not complete this part.

Most people received feedback and point deductions in this activity for issues with their plots or due to calculation errors. For example, the instructor deducted points from four students' worksheets for their plot titles. Two students had points deducted for not including a plot, or for issues with the scale of the plot. And, three students had points deducted by the instructor for errors in calculating the magma speed. For synthesis in question five, one student appeared to confuse the terminology, which caused the instructor to deduct points. Everyone appeared successful at the webcam question at the end and most students appeared successful at the higher order thinking questions. Student eight wrote at the end of her activity worksheet, “honestly, in the beginning I was really confused and overwhelmed, but after many hours, I finally got it and was very excited (especially after finding the deflation video – everything started to make sense!!!)”.

Greek earthquake problem set. Grades on the ten Greek earthquake problem sets ranged from 84-100%, with the average being 94.3%. Four people had points deducted by the instructor for calculation errors in part one and five students had points deducted for details with their plots, but overall, the students appeared to perform better on this activity. Only two students received feedback for errors on three questions later in the problem set (one for appearing to miss a foreshock, and one student appeared to miss that the pattern of aftershocks was scale-independent).

GPS problem set. Grades for the ten GPS problem set activity worksheets ranged from 78-98%, with an average of 89.9%. On approximately 15 questions, one to three students received feedback from the instructor indicating errors with calculations or simple errors with wrong directions for a total of 14 lower order thinking type question errors. In terms of higher order thinking type questions, for question twelve, an evaluation type question, four students had points deducted by the instructor for what appeared to be missing that the monument was far away from the fault. For question 16, an analysis type question, three students had points deducted for indicating the opposite direction of increasing instead of decreasing. And, for question 17, a synthesis type question, two students received feedback that they did not correctly predict where the plate boundary existed in relation to the GPS data.

In part three, for question six, an evaluation type question, it appeared that five students missed the bigger picture and that the monument was located far away from the fault. But for questions nine and ten, synthesis and evaluation type questions, only two and one student, respectively, received feedback from the instructor and points deducted for either calculations or for not providing an adequate answer.

Summary. Feedback and comments provided in the students' graded activities were mainly in reference to errors or for areas for improvement, but most students appeared successful at the activities, and at the higher order thinking type questions, as indicated by no feedback or corrections made by the instructor in the students' graded activity worksheets. The instructor's feedback was specific and on-point where errors occurred. Feedback in terms of calculation errors usually was to point out errors, and she provided equations with steps showing her work. For plots, the instructor provided feedback about correct plot titles, labeling of axes, using the appropriate scale for data points, and being more descriptive. If necessary, she would provide her plots of the data to show the student a correct plot. The instructor also provided constructive feedback for answers not necessarily incorrect, but if she wanted something expressed in a more appropriate or clearer way. For example, for one student, she wrote, "Right, exactly. Deadliness is a function of the eruption itself, but also human factors, such as how many people are living nearby, if they had time to get away, and whether historians documented it." And occasionally, she provided short positive statements, for example, "Right! Good!", which I interpreted was at least in part to show her presence and that she reviewed the student's work, even if she perceived everything as being correct.

Discussion Forums Observation Results

Two general discussion forums were related to, and contained, discussion about the lab-type activities. A Questions discussion forum that was open throughout the course, and three Teaching and Learning discussions that occurred at specific times in the semester. Below is a summary of the discussion that occurred in these discussion forums related to the lab-type activities. Starting posts are meant to refer to the first post of a new question or idea in the discussion which may or may not have started a thread of discussion and interaction following it.

Questions Discussion Forum

Of the 38 total starting posts in the questions discussion forum, 26 were related to the lab-type activities, and in the threads of these starting posts about the activities, there were 41 replies made by students, and 36 by the instructor. The nature of posts made by students about the activities in this discussion forum appeared to be for the purpose of checking answers, asking for clarification, or for explanation of concepts or problems. Because this discussion occurred before the students submitted their activity worksheets, I assumed that the student who asked the question and others in the course with access to the same feedback in the discussion forum would have read and used the feedback from the instructor to correctly answer the question in the activity. Therefore, I checked their activity worksheets for evidence that the specific question discussed correlated with correct responses students made for that question.

Paleomagnetism problem Set. One starting post was made in regards to the paleomagnetism problem set. Student four posted a question, which I classified as seeking information, for hints or pointers as to where to begin with the problem set. The instructor replied a response that first assured him that the problem set was probably easier than he was expecting, and she stated:

> In Part 4, #2, see the little tick mark where it says '100' to the right and left of the zero? That is the point in space that is 100km away from the center of the spreading ridge. I'm just asking you, which geomagnetic epoch corresponds to that point? And then you can refer back to the figure you used in Part 3 which also has the ages.

Her response did not provide answers, rather it was characteristic of discussion posts that explain, mentor and scaffold, according to the description in Zhu's (2006) analytical framework for cognitive engagement in discussion forums (Appendix D), by offering suggestions for on what to focus, where to start, etc. She also mentioned another student's research on a scientist whose work was relevant to this topic, but mixed up the student who actually presented on this scientist, so the next four replies were just discussion to correct this. Everyone in this offering of the course appeared to have this part answered correctly in their graded activity worksheets, but student eight received feedback from the instructor for a calculation error on one of the questions.

Optics lab. Three starting posts were in reference to the optics lab. Two of these posts were generally the same question that students had in two different offerings of the course. The question referred to a part of the activity where students were asked to determine the largest angle of refraction possible and measureable in their experiment set up. In student three's starting post, he posted the question from the activity and then speculated on the possible answers, offering some scenarios, but was unsure and appeared to be seeking information. He included a picture of his setup for this question. This post was unanswered, but he appeared to have completed this correctly in his worksheet. Two students in this offering of the course had points deducted by the instructor for what appeared to be that they did not answer based on their actual experimental set ups.

Student seven, in a different offering of the course, made a starting post, appearing to be seeking information, and asking if the angle of refraction could be greater than 90^o. The instructor replied with a mentoring type response that explained how understanding of this is reached and why the angle could not be more than 90^o. She also mentioned limitations in measurements due to the set up. Student seven responded, "thank you that it what I thought", but on her graded activity worksheet, she had point deducted and appeared to mix up incident versus refracted angles. Student eight also posted, appearing to be seeking information to check her calculation on this part. The instructor replied with mentoring and scaffolding type replies, explaining how the calculation should be done, common errors that can occur, and suggestions for her to look at this and re-evaluate her calculation. Student eight appeared to do this correctly in her activity worksheet, but student four had points deducted by the instructor for an error in this part.

Student seven also made a starting post with a technical question, appearing to be seeking information, about how to draw a line in a graph in Excel. Student eight replied with an explanatory type reply explaining a method she used. The instructor replied with a scaffolding type reply, telling the student to remember how to calculate something without making a common mistake of using the reciprocal of the slope of the line. Both students seven and eight had points deducted by the instructor for errors with this in their graded activities, but for not setting up their plots correctly, not for what was discussed in this discussion forum post.

Snell's law problem set. Seven starting posts were made about the Snell's law problem set. Four posts appeared to be for checking results that the students perceived as incorrect. Student one posted a question about the p-wave travel time curve problem set, because she stated that she received conflicting answers from what she expected (a farther seismic state resulted in a closer time travel distance). She seemed to be seeking information but also evaluating her data and noticing that something did not seem to make sense. The instructor responded with an explaining and mentoring response. She suggested a specific calculation for her to double-check, a problem where she commonly sees mistakes, and a possible problem with sign for east and west longitude. Everyone in the course appeared to do this correctly in their graded activity worksheets.

In a different offering of the course, student five posted appearing to be seeking information and checking if an answer he received was correct. The instructor replied, first asking for clarification about the specific question, and she then gave an analytical type response to answer each question to which he might have been referring. Student five replied that there was a mix-up in the question numbers between the worksheet and website, but provided his calculations. The instructor replied that she would fix the question numbers and explained the problem in more detail, and this time with a diagram. Student five's posts were analytical in nature, and the instructor's posts were mentoring to show how the answer was found, explaining that it is a geometry rule, and scaffolding type response to point him towards success with this question to re-do his work and get the correct answer, but without giving any answers. Student five responded, "boy do I feel foolish! Especially since I just got done teaching about eratosthenes (sic)". To this, the instructor replied, "but you've probably never had to apply it to an actual problem before, out of context, which is harder!" I interpreted these interactions as the instructor invoking student five's prior knowledge of the geometry rule and utilizing it in this problem. It also directed his attention to the meaningfulness; he taught this concept but seemed to overlook that it had relevance in a different context. Student five appeared to have this correct in his graded activity worksheet, but student four had points deducted by the instructor for an error with the calculation for this.

Student seven made a post that seemed to be seeking information and information about her calculations, which she also posted. The instructor replied with a mentoring type reply explaining why the calculation was ending in error on her calculator, and she directed student seven to the thread described above, where she could find more guidance in a similar question already discussed. Student seven replied that the thread helped her to a point, but she was still not sure how to solve for a particular angle, and she appeared to be seeking more information. The instructor replied with a scaffolding question "can you find the other angle in the diagram that is equal to the blue angle?" Student seven responded and asked a clarification type question, seeking more information, and the instructor replied that she was correct. Everyone appeared to have this correct in their graded activity worksheets.

Two posts were related to interpretation of the first arrival of the p-wave on seismograms. One of these posts was made by student five wanting to check his plot on which he saw two “odd ball” points. The instructor replied with scaffolding and mentoring type replies, pointing out the likely cause of the error being his pick of the first arrival of the p-wave on the seismograms for those stations, and she explained how this can happen when background noise is greater at that station. She supplied her calculations for the student to compare. Student five responded that her explanation helped him find the error. Everyone who completed this in their graded activity worksheets appeared to have it correct.

One post about the Snell’s law problem set that occurred in a different offering of the course was not to check results, but rather appeared to be seeking clarification and more explanation on determining the first arrival of the p-wave on seismograms. The student posted questions, seeking information, about how to interpret seismograms and static in seismograms. The instructor replied with an explanatory type response explaining how the seismographs operate and she explained in reference to specific stations where there was noise visible versus no noise. This directed response was analytical in nature and pointed out to the student specific parts on which to focus and compare, but also mentoring as she explained how to arrive at the correct answer. She also included screenshots for him illustrating to what she was referring. All students in this offering appeared to have this correct on their activity worksheets.

Two posts about the Snell's law problem set were specifically in reference to a question in the activity asking about toward or away from the normal in predicting refraction angles. Student five asked for clarification about the terminology and concept. The instructor replied with an analytical response breaking the information down and explaining in more detail, but also explaining the concepts and why the terms were described as they were. Student five had points deducted by the instructor for this in his graded activity worksheet; he appeared to switch toward versus away from the normal. Student four, in this same offering of this course but in a separate starting post, posted his drawing predicting the angles and seeking information to check his results. Student five replied with a supportive and informative comment stating that his diagram looked similar. The instructor responded that both students were correct. Student seven also posted in this thread seeking information and wanting to check her calculation that was slightly different from the other two. The instructor replied to her, as well, with an explanatory remark that her answer was within error and correct. Everyone appeared to have this correct in their graded activity worksheets.

Eruptions problem set. Five posts to the questions discussion forum were related to the eruptions problem set. Two posts were in reference to problems with the open resource needed for this problem set. Student three posted a question seeking information and asking why the Hawaiian Volcano Observatory site was not providing data for a certain part of the problem set. Two students responded that they were having the same problems. The instructor responded that she spoke with the administrator of the site, there was a problem with the servers, and it was being addressed. She instructed them to move on. No one in this course offering had this part done in their graded activity worksheets.

Two posts were related to how to do something in the eruptions problem set. Student seven posted a question, appearing to be seeking information, for how to calculate magma speed. Student five replied with an informative post stating how he answered the question. The instructor replied with an explanatory, mentoring and scaffolding type post. She elaborated on how to calculate speed and explained certain elements of the data used to do this, then she explained a method to do the measurement. She also directed the students that some of the decisions for this and for the data must be made by the students on their own. Student seven replied confirmation that she figured out how to do this part. Everyone appeared to have this correct in their graded activity worksheets.

Student eight posted two questions seeking information about how to find certain data about a volcano which did not have information given, and what specifically to plot for the volcanoes. This began a thread of interaction mainly among three students over four posts sharing similar questions, and offering suggestions and evaluating options for how to solve the problems and design the plot, ending with student seven offering her interpretation of what was being asked in the activity worksheet. These interactions occurred over several hours, from the evening of one day to the morning of the following day when the instructor replied with mentoring and scaffolding type responses, explaining methods to make the plot, what to show, and how to find information and make a conclusion. The instructor stated, for the volcano in question, “it’s a little bit of a trick question. Nobody was around in the Pleistocene to record it, but you can make a guess given it was a caldera-forming eruption, right?" This thread ended with a post from student seven in which she appeared to analyze and synthesize the conversation to this point. She stated:

> so since the last eruption at Primavera has more rhyolite that means it has a higher silica content. With a high silica content the lava flow would be more viscous and move more slowly so it would cover less area. It also means that the VEI was probably on the high end and so would the volume, right? I hope I am headed in the right direction.

Everyone appeared to have this correct in their graded activity worksheets.

Student three, in a different offering of the course, posted a similar question about the same volcano. He found the necessary information for other locations, but not that one particular volcano, so he was seeking information about where to find this data. The instructor responded explaining that the information is not given because the eruption occurred in pre-historic time, and mentoring the student to infer the data from what they already know. Student two posted a question appearing to be seeking information about what specific data they should plot, and the instructor replied with an informative response stating to use both pieces of data student two mentioned. Student two then replied again seeking more information and a clue for how to do this, but no reply was made to this post. Everyone in this offering appeared to do this correctly in their graded activity worksheets.

Earthquakes problem set. The Questions forum contained six starting posts about the earthquakes problem set, which ranged from a technical question, to an unexpected result, and several questions asking for more explanation of concepts and how to plot data. Student five posted the technical question, reporting a change to a website and asking how they should proceed. The instructor replied stating that she would fix the problem, and posted directions for how to access the website in the meantime. The instructor posted again to inform the class when the link was fixed.

Student five also posted appearing to be seeking information about receiving an unexpected result, evaluating his data and not seeing a specific earthquake over the time span he was analyzing. The instructor responded pointing out that he was incorrect about the date of the earthquake, which actually occurred three years later. Student five responded that he misunderstood and figured out his error. He and everyone in this course offering appeared to have this correct in their graded activity worksheets.

Several students posted more general questions. Student nine asked the instructor to elaborate on background seismicity. Student three replied appearing to be seeking information on this topic, too, and posted another extension question, asking for more detail specifically about distinguishing low magnitude earthquakes from background noise. The instructor replied a mentoring type response, in a long paragraph explaining the difference, and concluded by synthesizing the information. Student three also posted a starting post asking a general question and seeking information about how to read origin time, and the instructor replied explaining how to read the time.

Student seven posted that she was having difficulty with a plot, appearing to be seeking information and any suggestions. Student four replied an informative type post in which he posted his plot, but stated that he was not sure about it. Student five replied explaining and mentoring how the information should be found, and showing an example of his plot. The instructor replied that student five was correct and mentored and explained another way to find the information. Everyone appeared to have this correct in their graded activity worksheets. This interaction prompted the instructor to make an informative starting post informing the students that she made a screencast of herself doing a plot for this part. Student seven replied appearing to be seeking more information about time span. The instructor replied with an analytical and mentoring response giving examples and analyzing the time span.

GPS problem set. There were four starting posts for the GPS problem set in the questions discussion forum, which again varied from a technical post to more evaluative type posts. Student five posted an informative post about a link not working in the worksheet. Student four made a mentoring type post explaining how he obtained the data without using the link. Student seven replied an informative post that the link was not working due to servers being down, and sought information about what to do next. Student five asked if they could skip that part, and the instructor replied explaining and mentoring, adding to what student four did to find the data. All students in this offering appeared to have this correct in their graded activity worksheets.

Student six posted appearing to be seeking information about how to calculate recurrence interval. The instructor replied asking for clarification of which part in particular, but still gave directions and mentored how to do the problem for whichever part student six was referring. Student six replied gratitude and informed to which part she was referring. Student six appeared to have this correct on her graded activity worksheet.

Student three posted a question which I interpreted as indication of synthesizing and evaluating information. He noted that the stations were on opposite sides of the San

Andreas Fault, and expected that the stations would move in opposite directions, but observed that they were moving in the same direction. He asked for more information about this unexpected outcome. The instructor explained and mentored why this occurs. She also related the concept to cutting a pan of brownies, thereby relating it to observable and familiar processes, and linking to the student's prior knowledge. However, student three seemed to misinterpret this, as he placed the stations on the wrong plates in his activity worksheet. Everyone else in the course offering appeared to have this correct.

Student seven posted that she was evaluating her work and found what she thought was a mistake. She posted appearing to be seeking information for how to calculate rate and direction. The instructor replied explaining how to calculate it, but that she was correct. Student seven appeared to have this correct in her graded activity worksheet, but two other students had points deducted by the instructor for errors in their calculations.

Summary. The nature of posts made to the Questions discussion forum appeared to be mostly for students seeking information about specific questions in the activities or specific concepts for which they needed more explanation. Eight posts alluded to the students synthesizing and evaluating their data, for example, students who posted because they stated that they were questioning the results they received, such as student three questioning why GPS monuments on opposite side of the San Andreas Fault were moving in the same direction. Many times, other students participated, replying to ask more questions about the topic of the first question, or appearing to try to provide guidance to the other students. In four student replies, students' posts were characteristic of them acting in mentoring roles to help each other. For example, student five stated how to find information and make a plot in the discussion about the earthquakes problem set, and student four stating how to obtain data without relying on a broken link in the GPS problem set.

The nature of the instructor's posts was characteristic of mentoring and scaffolding to guide the students to understanding and help them to solve the questions or problems. In a couple of replies, the instructor's comments appeared as attempts to trigger the students' prior knowledge and utilize it in the new problem, for example, directing student five to recall rules of geometry, and relating plate boundary drag to a knife through brownies. Evidence of meaningfulness also occurred in student five's thread and in relation to refraction of seismic waves and rules of geometry that he taught. The instructor's participation was also very timely. She most often replied to students' posts within hours, or the next day. Only in three instances did she reply two days later, and in one instance, three days later.

Teaching and Learning Discussion Forums

Three Teaching and Learning Discussions occurred through the course and the purpose of these discussions was for students to reflect on the content and activities. The instructor stated on the open website, "consider how you might adapt these materials to your own classroom or share the ways in which you already teach this material". Starting posts discussed in this section are students' first posts of their reflection about the activities.

Teaching and Learning I. The first teaching and learning discussion occurred in lesson four. Students were directed to reflect on lessons three and four, in which, they completed three lab-type activities: the paleomagnetism problem set, the optics lab and the Snell's law and travel time curve problem set. Of the 53 total posts that occurred in the first Teaching and Learning Discussion, 27 posts were related to use of the lab-type activities and their use in teaching. Of these, most posts, 18, were about the optics lab. Nature of other posts in the discussion were for sharing resources, or other content from the lesson, for example, the "research your own scientist" and the magnetic field concepts.

Four threads showed meaningfulness and reflection about the optics lab, and mainly for use in teaching physics topics. For example, in the summer 2012 offering, student nine posted indicating that he reflected on the optics lab and usefulness of this lab in his teaching both physical and Earth science. He stated that the optics lab would be useful for him as a cross-over type lab from refraction of light through water in physical science and then translating that to seismic waves in his earth science portion for the students he had two consecutive years. He stated:

> not only can I use this to allow the students to explore the optical properties of water, I can then use it again the following year, therefore reinforcing prior knowledge while simultaneously applying a basic principle to another area such as the properties of seismic waves/Earth interior.

And, student three stated similarly that he could use the optics lab for teaching about light and sound in the physics unit. He stated that he wanted to include optics into his teaching, but could not cover the details due to lack of time. Nevertheless, he stated "I think this activity is a great way to help students learn the fundamental basics of these concepts, even if they don't have much prior knowlege (sic) going into the topic". He elaborated on what parts he could use, what he would divvy out to groups, and what he would need to do differently to make it appropriate for his students' abilities.

To another starting post about the optics lab in reference to teaching about refraction, seven student replies, from three students, either added agreement and support, asked additional questions, or offered suggestions for how to do certain parts. Several comments were also in reference to using photos to help model the lab for students. Student two joined in this thread, adding that she does not teach face-to-face, but contributed a short statement about how she would incorporate videos to explain the information to do the lab. In this thread, the instructor also replied stating changes that she would like to make to better explain the lab, to make videos doing the lab rather than having only the pictures. Student nine replied to this adding that he appreciates the video software she uses for other demonstrations in the course.

In a different offering of the course, student five mentioned a technique he uses in teaching, then reflected on the optics lab, and stated that the optics lab would be too advanced for his students. He asked thoughts from the rest of the class about this. Student seven replied stating that she thought the students could do the activity with enough guidance. Student four replied that he was not sure, but added another application/extension of the optics lab, to observing objects in a swimming pool. The instructor also replied twice adding more ideas for using the lab, one in which she suggested collaborating with the students' geometry colleague at their schools, but a reply to this showed frustration with having an uncooperative geometry teacher.

In this same offering of the course, the instructor made a starting post asking the students their thoughts about the use of authentic data in teaching, and the challenges of incorporating it into their teaching but at their students' level, without overwhelming them. Student four posted about wanting to use authentic data in teaching, but mentioned the struggles of trying to deal with the students' poor math skills. Students five and seven replied appearing to be empathizing and stating seeing similar problems. Student seven added that she would like to use a method the instructor used. The instructor replied also empathizing about seeing similar patterns in college, and in science. This whole conversation seemed to center on the poor transfer skills of the students' students.

In summer 2013, the students appeared to reflect on all parts of the content, including the paleomagnetism and seismic waves in general, and the optics lab. Student six posted appearing to be reflecting on the activities and content, but expressing frustration about the curriculum in her school and the amount of background information that would need to be taught first. She found meaningfulness in the articles and earthquakes activity with simplification, but stated that she had poor results with the optics lab and Snell's law activity and thought the math would be too advanced for her students. Several interactions followed in which the students shared experiences and frustrations with the limited curricula to which they must teach, but they expressed a desire to cover this content more. These interactions did not show much reflection on the meaningfulness of the activities, but rather empathizing and wishing they could do these activities.

Teaching and Learning II. This discussion took place in lesson six. Students were directed to reflect on lessons five and six, in which they completed one lab-type activity, the eruptions problem set. In total, there were 16 starting posts, 58 student replies, and 23 replies from the instructor. The nature of most posts to the discussion were to share a resource or demonstration, share how they teach volcanoes, or reflecting on the forensic geology lesson plan. In the summer 2013 offering, the instructor started the conversation with two starting posts asking the students what they teach about particular topics and how well their students understand these topics. While there was discussion in this forum, none of the discussion showed reflection on the activity.

In reference to the activities, there were three starting posts about volcanoes and the eruptions problem set, six student replies to these posts, and four replies from the instructor. Student three stated that his students may not have the geology knowledge or background information needed to understand the dynamics of volcanoes; therefore he could teach only basic information. He stated rather than using the VEPP site, which would be too challenging, he discovered a resource the instructor posted in the additional resources page at the end of the lesson that he would use. He appeared to reflect on this resource; he stated positive aspects of it and how he could use it in his teaching. Student two replied sharing another resource, and two conversational replies, including one from the instructor, followed this.

In another series of posts, students discussed a different resource not used in this course for volcanoes, and focused specifically on supervolcanoes. And, in a different offering of the course, student five appeared to reflect on the different monitoring devices used in the VEPP system, but did not discuss the use in his teaching. He speculated and asked if there were monitors to measure magnetic properties of iron-rich lavas, and he related this to his knowledge of the iron-ore deposits in Pennsylvania. This post appeared to show that he was relating the new information to his prior knowledge. And, of the three posts about the eruptions activity in this forum, only this post seemed to show reflection and meaningfulness about the activity.

Teaching and Learning III. This discussion took place in lesson eight. Students were directed to reflect on lessons seven and eight, in which they completed two lab-type activities, the Greek earthquake problem set and the GPS problem set. It is not shown on the course page for lesson eight, like the other two lessons, that this discussion is graded. Of the total eight starting posts, 20 student replies, and seven replies from the instructor, only one starting post by student three was related to an activity and appeared to show reflection and meaningfulness of this activity. This post actually pertained to part one of the eruptions problem set from lesson six. Student three wrote that the Global Volcanism Program would be a useful resource for using physical evidence to discern different sized volcanic eruptions for his students, and how different types of volcanoes produced different sized eruptions. He stated:

> I would need to spend a day or two teaching my students about tephra volumes and how an explosivity index is calculated, but in the end, I think once they see the plots showing the relationship, it could be very helpful when proving to them that each volcano and its own corresponding eruptions are unique. It is also a great way to show them the difficulty of the job of a seismologist or a volcanologist when attempting to predict these sort of events in the future.

The nature of the majority of the starting posts in the Teaching and Learning discussion III in summer 2012 was for sharing resources, links, and useful websites. Discussion was started by the instructor in the spring 2013 offering with two posts asking the students about a teaching framework and content they teach. There were no posts to the discussion in the summer 2013 offering.

Summary. In the discussion about activities in the Teaching and Learning discussion forums, seven students appeared to reflect on, and find meaningfulness in, the optics lab, and one student on the eruptions activity. Two students appeared to reflect on the Snell's law activity, and one on the eruptions activity. For the optics lab, two students stated seeing use of it in their teaching of physics content, one for use with the concept of refraction, and one for use in online teaching. Two other students appeared to reflect in response to a student's skepticism about the use of it in his teaching. They mention that the simplicity and ease of set up for this lab were advantages of it. For the eruptions activity, student three appeared to reflect twice on the meaningfulness of this activity. He stated finding part one of the activity useful as-is, but determined he would need to switch part two to another open resource provided by the instructor. And, student five appeared to reflect on the eruptions activity and asked a question based on what appeared was his own curiosity. His reflection showed what I interpreted as utilization of prior knowledge and meaningfulness in terms of tying the information to his existing knowledge. The biggest obstacles mentioned for the use of the activities was in the level of math involved, and the advanced level of it compared to their students' knowledge. For example, the two students that appeared to reflect on the Snell's law activity did not find meaningfulness in it due to resigning to the conclusion that the math involved was too advanced for their students, and due to curriculum constraints. This was also noted as an obstacle in the use of authentic data in general. Constraints due to time and the limited curriculum were also mentioned as obstacles to using the activities.

Interview Results

This section summarizes the information gained through interviews with each of the ten students. Common ideas that emerged from the responses were summarized for each interview question.

Main Question One: What Was the Role of the Activities in Your Learning?

Students' responses to this question showed that the students perceived that the role of the activities was either to aid in their understanding of the content, or to provide them with new experiences analyzing real data.

Aids understanding. Seven students gave responses to this question which I grouped into the category of aiding their understanding. Four students stated outright that the activities aided their understanding. Student four stated that the activities "helped me understand the content more completely". Student seven stated that the activities "gave me a better understanding". Student eight stated that the activities provided an overall "idea about plate tectonics and how to study their movements, and just learn how they were set up". And, student nine stated explicitly that the activities "definitely connected to the material, that's for sure, and it helped me understand it". He stated that the activities related directly to the topics and illustrated the concepts better.

Three students elaborated that it was the complex and in-depth nature of the activities that aided their understanding. Student one stated that the activities were long, requiring several hours to do the work, and requiring concentration. For example, she stated that, at times through the semester, she was unable to complete an activity in one siting, and then would need to return to the activity at a later time. She reported some frustration because the activities were so detailed and later parts built on previous parts, she would need to refresh her memory of earlier work, because in the end, an analysis of it all would be required. But, she stated that the fact she had to work at the activity helped her understanding, that “struggling with it a little bit actually makes you understand it a little more, than it just being given to you”. Student three stated that they take “sets of data and really getting involved with the data itself in order to understand general objectives she had outlined for the class”. He stated that there was a large amount of math, equations and problem solving, but “once you saw how it all worked out, it really helped you understand the underlying concepts, and when you combined that with discussion forums and similar discussions, it really brought out the meaning behind certain laws and different topics that were covered in each lesson”. This notion of multiple sources of information and methods was also mentioned by student six. She stated that the activities were “the main part of the learning” because they were intensive, but that was aided by the fact that they were included in an online course. As she worked on the activities, she stated:

> I have the internet in front of me, for instance, or books or whatever research material, I can go a little deeper, I can make sure I understand something using other websites, also being able to take my time, I tend to be a fairly slow worker and so, having unlimited time to complete them is useful to me.

Her responses imply that it was the culmination of the accessibility to multiple methods and sources for information and support, and the focused, self-paced work that made the activities learning experiences.

New experiences with real data. Three students gave responses that I summarized into a category as the role of the activities was to provide new experiences with real data. Student three stated that “I had the classroom experience, but I actually think through this program and these courses, the labs online are so much more in-depth that what I had in the classroom”. Specifically, she stated that it was gathering, using and analyzing the real, online data that made the activities unique. Student five elaborated that it was real-life problems and contexts that made the activities valuable. He stated that the role of the activities was, rather than just “learn some of the techniques, and learn some of the formulas, I think it was to apply to real life problems sets, which I really enjoyed, that it was showing real life problem sets that connected to our studies”. And, through the activities, student one reported seeing science and raw data as an open-ended process with unexpected outcomes, which she reported was a new experience for her. She stated that the students were given the means to do an activity, but the results were up to the student to figure out. She stated that it was “kind of like a self-discovery”.

Main Question Two: How was the Instructor’s Guidance through the Activities (Both Written Directions and Feedback in Discussion Forums) in Your Learning?

Most of the students reported more than one characteristic of the instructor’s feedback, which I organized into four categories: her guidance and directions were clear, detailed, guided and appropriate; she was involved in the course and encouraged discussion; she provided detailed feedback on graded activities that further encouraged learning; and her feedback was always timely.

Clear, detailed, guided and appropriate guidance and directions. Eight students reported that the guidance the instructor provided in the open course site and through the activities was clear, well and appropriately illustrated, where necessary, with images, screen shots and videos. Students four and eight stated that the directions were clear and helpful. Students one, two, seven and nine further added that her screen shots and videos, in which she models actions the students will do, were valuable and helpful. For example, student six mentioned that "little videos that she has embedded into the text that give the information about the activity and also about the content that goes with the activity were extremely useful". And, student nine stated, "that's what makes her awesome". He stated, specifically about the optics lab, that "she had a picture of the set-up, and she had her Pez dispensers, she's taking it from different angles, it's just step-by-step" and difficult to do incorrectly. Student two noted that the instructor was proficient with tools that allowed for illustration of the directions. And, student seven elaborated:

> those are so helpful because then you're able to go back, I mean if you're in a classroom, and the teacher is showing something, you only see it that one time, you can't go back and reference it, but her with the screencasts, it's like she's right there with you and she's showing you how to do something and you're like, wait a minute, what did she just say, and you can go back and you can listen to it again, and watch it again, and it just, it helped tremendously, because then I actually knew whether I was on the right track or I was going down the wrong road.

To convey their perceptions of the instructor's guidance, students two, three and seven compared the instructor's directions and guidance to other instructors' directions. Student three stated that the instructor was "by far the most detailed, explicit best feedback professor I've had". Student two stated, "I remember having to ask other professors for more information", but that was not necessary in this course. And, student seven stated, "now I have something to compare it to", implying that the instructor's course "set the bar" for her other courses.

Student three commented on how her guidance and directions were just the right balance. He stated that he empathized that achieving the right balance could be a challenge:

> if I were to develop a course and I really had to make sure my students, at least online, understood what was going on and what was expected of them, I'm sure it's very hard to be concise but at the same time, you don't wanna get too detailed so that everybody's reading a thousand pages of directions, she made it flow in a way that you got the idea, but at the same time, she make you think a little bit as to what you were supposed to be doing, and where you had to go, I think she creates a very good balance to the flow of the classes.

Involved and encouraged discussion. Five students commented on the instructor's presence and how involved she was in the course, the nature of her participation, and use of technology encouraged discussions. Student three commented on that fact that the instructor participated in discussions, stating "in my other classes, there was no discussion like that, we would make one comment on one of our classmate's thing and nothing would go from there, there was never anything added by the instructor, and so this helped us tremendously". He stated that it felt like a discussion in a classroom and that the discussion would continue over time. Student nine stated of other classes, "I don't really recall too much the instructor's chiming in, where she does, like if she sees an opportunity to further the discussion or have us think about something differently, she just chimes right in, she's like, 'hey, why don't you…', she'll ask a question". He stated that she likes to "egg you on, so that's pretty good". Students one and seven also commented on the nature of the instructor's participation. Student one stated that the instructor participates in discussion to guide thoughts, but "there's never really an answer". And, student seven reported that the instructor would redirect students working ahead to focus on the questions and topics being covered at the time. Even in e-mail interactions, student seven stated that when she would e-mail the instructor with a question about something she thought was incorrect, the instructor would give her a hint, without providing the answer. Student seven stated that "was better for me because that gave me the opportunity to figure it out on my own, and then all of the sudden I would see my mistake".

The instructor's use of the technology also seemed to encourage discussion. Student seven stated that she properly utilized and encouraged discussions. She gave the example that other instructors would use the discussion capabilities in the external open website, but its design was not as conducive to discussion as the discussion forums in ANGEL, which this instructor used. She stated, "it's just a matter of somebody knowing how to use the system versus not knowing how to use the system, and she's very equipped at that". Student three also noted that "she has the class set up is so much better than any of the other classes I've taken, because she actually uses the system properly".

Detailed feedback on graded activities that encourages learning. Eight students reported that the instructor's feedback on their graded activity worksheets was detailed and specific, both to point out errors but also for parts done correctly. Student one stated that:

> she would have the grade in the e-mail, and you would open it up, and it had everything like if we'd gotten something wrong or she didn't like something, there'd be comments everywhere, and if we did do something wrong, she'd point out where and how she got her answer, and then ask us how, if she didn't understand how we got ours or point out what we got wrong or why we may have come to our conclusion.

And, student three stated "it was good feedback, it wasn't just this is bad, this is good, it was deep, it was enriching, you could tell she took the time to literally look and find and help you solve certain parts of the lesson".

Three students further elaborated that with the feedback the instructor provided in their graded activity worksheets, they would review and reflect on their work to understand what they did incorrectly, even though she they did not receive grades for correcting their work. Student three reported looking forward to the feedback because "fixing those mistakes led me to be much better", and student seven stated, "it helped me because then I would go back and see where I made my mistakes and where I needed, and you know it helped me to learn more, too".

Timely response. Nine students reported that the instructor's feedback was timely, generally within a day or two, in response to e-mails, and in discussion forums. Student eight stated that, "you didn't have to sit there and dwell on a specific problem set, you know, it was very quick response, you could move on and complete the project". Student seven stated that her timely responses in discussions further encouraged discussions among the students, and even if the instructor missed that some content changed in the course, she was quick to place a new screencast in the open website that made sense with the changed content.

Main Question Three: What Was the Role of Interacting with Other Students in Your Learning from the Activities?

Most of the students reported to this question that the role of interacting with other students about the activities was for support and to compare and check their own work, but the students that did not report this, either only seemed to recall the readings discussion forums, which were not directly related to the activities, or one student, student six, reported that there was very little interaction with the other student about the activities. She stated that the discussion with the other student was "somewhat helpful", but several factors limited the use of it for her. For one, there were only two students in this offering of this course, and they were at different points in the program; this course was the other student's last course in the program and student six's first course in the program. She stated, "if there were two new people taking this course, then maybe it would have been more vigorous, but I think that had something to do with it". She also stated that she had only two questions about the activities that she posted in the discussion. She stated that, "generally speaking, both of us didn't have a lot of problems with the coursework".

For support, comparison and checking work. Six students reported that the discussions were beneficial and supportive for help, comparing and checking their work before submitting it. Student one stated, "I would be the one posting the questions, like 'I'm stuck here'", and she would use the feedback to compare with what other students did in the activities. Student four reported not always trusting the answers he received on his activities, so he would use the discussions to review questions posted by other students. This helped him to see if he was doing the assignment correctly and to work through the problem sets. Student nine valued the discussions also to see other points of view for the activities. He stated, "it was neat to see how others approached, or just think differently, so it can alter your point of view, as well, so that *was* nice, so the discussions are the key, I believe". And though students used the discussions to compare work, no one would post answers. Student eight stated:

> people were pretty clear on the steps that they took, but not clear enough that they would just give the answer, you know but just trying to step-by-step help people along, or if there was a problem where it took a lot of work to get the answer, they might say like my answer was in this area, so at least you knew you were in the 10, the right power, you know, and even graphs, like an outline of their graphs to show what their shape looked like instead of actually their plot.

Main Question Four: How Well Did Doing the Activities Aid in Your Understanding of the Content?

All students reported that the activities aided their understanding, but when they elaborated, a variety of responses were given to this question. I grouped these responses into five categories, which were: the activities helped students to see *why;* the activities provided new experience; the interaction in the activities aided understanding of the content; the activities aided retention of information; and understanding in the activities was tied to use for the activities.

Helped them to see why. Students four, eight and nine reported that doing the activities helped them to understand why something happens the way it does, rather than just memorization or knowing concepts. These responses were in reference to the optics lab and Snell's law problem set. Student nine stated that he now knows "more in that area, because you don't necessarily think of *why* that it, I guess, and you know the speed of the light entering different mediums, so now I can explain that, whereas before I would be like, it just does". And, student four reported not understanding Snell's law when he first encountered it in his undergraduate mineralogy course, but now understands the topic better.

Provided new experience. Students six, seven and ten reported that the activities provided understanding and new experience. Students six and seven described new experience regardless of familiarity with the content or for later courses. Student seven reported having no experience with the content beforehand, and stated that "I understand them a lot better than I did before". And, student six stated that, "I actually learned quite a bit… I teach Earth science, I knew a lot of it to begin with so it wasn't huge leaps, but there were definitely things that I learned in terms of the content". Last, student ten reported that the new experience she gained was useful in later courses.

Provided interaction with the content. Two students stressed that it was the interaction with the activities that aided their understanding of the content. Student three stated that the activities involved, first, a procedure, then they would get into the "nuts and bolts and break apart and you discuss some things and then you kind of come up with an overall conclusion". He stated that this design and the amount of time required thinking about each part and tying them to the concepts gave him a very good understanding.

Aided retention of content. Two students reported that doing the activities aided their recall of the content and information. These two students had taken this course the previous summer when they were interviewed, and reported that they recalled the activities clearly because, they explained, they interacted with the activities. Student one stated that “it’s one thing to read the material, it’s another thing to actually work with it and I would have to say if I wasn’t working with it, I would not have retained as much information as I have”. She stated that she probably would have performed well in the course regardless, but would not have remembered the information as well as she did due to doing the activities. And, student nine mentioned being able to remember and recall the activities by just looking at their titles, rather than needing to read and refresh his memory, he stated, for example, “there was the dynamo that had to do with the Earth’s magnetic field, I’m imagining Earth’s interior and different layers”.

Understanding was tied to the use. Students two and three elaborated on the understanding in terms of how they could use the activities. Student two stated that some activities:

> would help me understand [the content] better to apply it to the coursework I was doing, but in some cases, I remember feeling a little challenged by either the math or some of the more challenging complex parts of this, saying to myself ‘I don’t think a kid’s going to do this in my course, and I know I’m not going to do this after this assignment’.

Student three reported a similar reaction to the activities, though he did not appear to dismiss more complex activities, but reflected on ways he could make them appropriate for his students. He stated, “although the concepts are much more complex than an 8th grade level, still the basics and the foundation of why you’re learning can be applied to even an 8th grader”. He stated that he viewed each activity through this lens, because it was his “job to bring information into the classroom and bring it down to their level”.

Main Question Five: How Meaningful Were the Activities to You, Meaning, Do You See a Use for Them in Your Own Teaching?

All students reported that the activities were meaningful to them, in that they see a use for them and value in their teaching. Five students reported that they have used parts of some or all of the activities in their teaching. For example, student one reported that she showed her students the animation she developed for the earthquakes activity, and used it as a discussion starter. She asked her students, “how many earthquakes do you think occur every year?” Based on their responses, which were always fewer than the actual number of earthquakes that occur, she would begin a lesson on earthquake activity and how frequent earthquakes are. She would also have the students analyze roughly 30 earthquakes, rather than over 20,000 that she did for the activity in this course, but she reported that they still learn the concepts. She also stated that dealing with the data and doing the activity in this course “was nice because you were actually working with real time data and material that I incorporate some into my classroom, which is kind of nice working with it myself”.

All students that used the activities made modifications to the activities to make them appropriate for the level of their students. Student three reported that this modification began with his reflection while doing the activities in this course about how he could modify the activities for his eighth-grade students. Student five stated that he would be using "bits and pieces, but that's probably pretty typical of how I approach a lot of my courses, it's rare that I experience a lab activity that I can have my students do the exact same thing, simply because of the difficulty and the concept level". Student nine used the optics lab with his middle school students in order to teach about properties of water in his physics and matter unit. He modified the activity to fit with the unifying theme of water, which he was using across several lessons. He also reported modifying the amount of math involved, and did not have his students do the trigonometry involved in the activity in this course, because this was beyond the level of math skills for his students. Student nine also reported using the websites and open resources in his teaching, and compiling these resources in an online portal accessible to the students. Student seven reported modifying an activity to make it appropriate for her online, undergraduate general education students. And, student two reported that she adapted activities into curriculum she developed, and even used the capstone project to make a lesson plan in which an activity was adapted into curriculum. She elaborated that having the real data in the activities made her more likely to use them in her work as a curriculum developer.

Five students reported that they have not gotten a chance to use some or any of the activities in their teaching, because either they were interviewed shortly after completing this course or were not teaching at the time, but they intended to use the activities at some point. For example, student six was interviewed over the summer, shortly after completing this course. She reported that she will probably use parts of the activities and the databases, especially the optics lab and the earthquakes database, with modification to the math for her ninth-grade students. Student ten stated that her classes were changing so that she would be teaching her first Earth science class in the upcoming year. She stated in her previous classes, she showed the students some of the activity websites or resources, but in her new class, she would be able to use more of the activities. Students four and eight did not have teaching positions at the time of the interviews. Student four stated that he would like to use either portions, or the whole activities, in his teaching. But, student eight stated that she would be teaching students at the elementary level, and while she viewed the activities as valuable, she anticipated modifying them significantly to be more basic and for students at that level.

Several students commented on obstacles to the use of the activities in their teaching. Three students noted that curriculum and time constraints dictated how much they could use the activities in their teaching. Student three stated, for the Earth science content, that “typically this was a topic I covered later on in the school year and so nevertheless, I wouldn’t have as much time as I needed”. Student five also stated that his incorporation of the activities depended on if he was teaching standards or content tied to Earth science. Student nine expressed disappointment that he would need to move away from teaching Earth science content to focus more on biology content to prepare his students for a state exam. This affected how much time he invested in implementing the activities. He stated, “that’s a shame because I had a lot of cool things lined up with the earthquakes, the volcanoes, all that stuff”.

Technological obstacles also affected the use of some of the activities. Student one stated that when she first learned they would be using an internet site for an activity in this course, she would see if the site was accessible on her school computers, if any of the content was blocked or if outdated javascript settings prevented data from being displayed. She stated she would typically have a student try to access a site, and if a student could access the site, then she would use it in her teaching. But, content blocked by the school or unable to run properly prevented student one from using that content from the activity in her teaching. And, student nine reported frustration with setting up class pages with the website resources and having his class pages wiped at the end of every year.

Main Question Six: How Do You View the Authenticity of the Activities, Meaning, How Reflective Do You Think the Activities Are of Actual Scientific Practice?

All students reported that they viewed the activities and the real data sources as being authentic. Three students in particular stated that they did not even question the authenticity of the data. Two students stated that they trusted the instructor's reasons for requiring use of the sites and data sources. Student five stated that, through the Masters of Education in Earth Science program, he knew the instructor and developed respect for her. He stated that he "didn't even question, to be honest, I never even put thought into how valid it was, it was the kind of, I approached it by thinking well this is what she wants us to be studying, it must be the ideal thing to study". Similarly, student four stated that he thought "if we were completing the assignments, that they were selected because they would be reflective of either teaching or scientific practice". Student one did not question the authenticity because she was familiar with the sites and knew that their work and data involved well-known and reputable sites.

I asked the students how the authenticity of the activities affected their perceptions of the activities, and categories of responses were observed. Students reported that the authenticity of the activities either increased their interest in the activities, or added meaningfulness to the activities.

Added interest. Five students reported that using real data and websites, or real situations, made the activities more interesting. For example, student two stated, "I felt like it was really an actual problem, not just a hypothetical one, which made me more interested in it". She also noted that this makes the activities more interesting to students, as well. Student seven further added that using the real data and website added credibility to the activities. And, student ten stressed that using the data and websites that scientists use made the activities more interesting and affected her understanding of "what scientists do".

Added to the meaningfulness. Six students stated that using the real data and websites made the activities more meaningful, and made them more likely to use the activities in their teaching. Student two again stressed that the data and activities were real rather than hypothetical, and this made her more willing to use that in her curriculum development. She stated that she tries to give students an "actual research based problem set". Student six, when asked to elaborate on why real data was desirable, stated:

> I think any time you show students the real thing, they understand that the real thing does exist,… because I think a lot in science, so much of what we are teaching kids, they're totally disconnected from it, and the

abstractness of it they don't understand, so anytime you can make it real for them, it's much more meaningful.

Three students stated that they were unaware of some the websites and real data resources used in this course, and being introduced to the resources provided them with resources for teaching. For example, student three stated he did not know about the open sources, and he and student eight both appreciated having access to these sources. Student seven further elaborated that she appreciated the experience with how to use the resources, and she could definitely use them in her teaching now that she is familiar with them.

Main Question Seven: How Did the "Teaching and Learning Discussion" affect your Perceptions of the Activities?

In response to this question, students reported most that the teaching and learning discussions were valuable to the classroom teachers for the collaboration or sharing of ideas for how to use activities in their teaching, but also that the teaching and learning discussions encouraged reflection about the activities. Student five did not recall the teaching and learning discussions, neither thinking positively or negative about them, or getting anything from the discussions. And, student six reported that she did not see a lot of value in the teaching and learning discussions. She stated that the instructor posted questions which sought concrete answers rather than encouraging expression of opinions, and "there was a tendency to just answer the question, which I didn't find that useful".

Collaboration and sharing of ideas. Six students reported that they found the teaching and learning discussions useful for the ideas posted by other students. Student ten stated "a lot of people had great ideas, we kind of shared ideas with each other, and it did help a lot to figure out how, okay, how can we use this in our classrooms". Student one reported printing, cataloging and saving the posts from other students about how to teach the content and use activities. Mainly, she found the posts very useful, but also contributed if she thought something could be taught in a better way, or if she used a different method for teaching. Student three elaborated on how it made him reflect on the activities then post his thoughts, and others would "feed off that", post what they tried in their teaching, and what others could try. He stated, "it was a good way to get everybody in the class to think together and then use the education side of it and our knowledge of how a classroom works to incorporate the lessons we learned in the course". Student eight stated that she could not participate very much because she was not teaching, but the discussion still gave her valuable ideas for how to use the activities when she does teach.

Two students reported that they had unique perspectives that added to the teaching and learning discussions. Student seven was the only classroom teacher in her offering of the course, and she reported in her interview, in response to the questions asking about her familiarity with other students in the course, that she felt slightly intimidated by the other students in the course. She stated, "some of them had never been teachers but they had big degrees in science". She felt that they had more to offer in the discussions about the reading material, but the teaching and learning discussions highlighted her strengths. She stated that she would comment to others in the course why, from a practicing teacher perspective, some of their ideas for using the activities might not work. She stated, "we were able to feed off of each other all through that discussion, and I thought that was really helpful, too". Student two developed curriculum for an online course, rather than taught in a classroom, but she also reported that her perspective and contributing posts about online learning was valued in the discussions. She stated that other students valued her input about online teaching, and developing content without time or curriculum restrictions classroom teachers dealt with. She stated, "I think it's proved to be an interesting dynamic for the class too because I had a different perspective on things".

Increased reflection. Three students also stated that the teaching and learning discussions increased their reflection about the activities. Student three elaborated on the reflective process he used for each teaching and learning discussion. He stated that the discussions:

> were a way to connect everything, if you had any doubts about the concepts going through it all, you could take the feedback that [the instructor] gave you and then really look at how you could piece this together into my setting in an 8th grade classroom, and I really tried to think about time wise, would I be able to do it, what state standards would I be able to incorporate this into, how does it relate to my curriculum that I already have.

Students four and six reported that they reflected on the activities before even posting to the discussion, and seemed to gain more from their own personal reflection than from the interaction in the discussion. Student four did not teach at the time, and he stated that the discussion forced him to "put more time and effort into the activities so that I could participate and contribute to the discussions". Student six did not seem to value the interaction with the other student in the class, but she stated that "most of what I got out if it was thinking about what I wanted to say".

Main Question Eight: How Deeply Would You Say that You Interacted with Content in the Activities, in Terms of Higher Order Thinking?

For analysis, did you break information or data in the activities down into smaller pieces, or make connections among disconnected pieces of data? Eight students reported that their analysis occurred as they were doing the activities in the order they were designed. Two students described specific activities which required analysis, for example, student nine described this in terms of the earthquakes problem set. He stated, that the analysis involved looking at long time spans of data and that they had to "keep thinning that time interval down and see if the relationship still holds", this involved analysis of the smaller parts. Student six reported that the earthquakes and GPS problem sets in particular also lent themselves to analysis.

Four students described how the instructor designed the activities to foster analysis and which also led into synthesis. Student one reported that each part had to be analyzed and completed because eventually, everything would need to come together in the end. Student ten reported that in the activities, each step had to be analyzed and then related to the next step. Specifically for the optics lab and Snell's law problem set, she stated "each concept had to do with the concept before, and it kind of extended your knowledge on it". Student seven described how the instructor had the activities set up to facilitate this and with the activities broken down into parts. She stated "that was beneficial because then it's broken down into chunks, so it's not as overwhelming". She further elaborated that they then had to take the data "to the next level". For example, with the earthquakes activity, students analyzed aftershocks, but then had to evaluate if a certain earthquake was an aftershock or another earthquake. She stated, "I thought that was pretty ingenious on her part because it wasn't just gathering the data and looking at it, it was actually taking it and analyzing it and figuring it out. So I thought it was really good at utilizing higher order thinking." And, student three described how the open data sources also facilitated this process. He stated that the data provided an open-ended view of science rather than concrete answers. The data involved manipulation of variables, but in the end, general conclusions and descriptions were made, and they were related to underlying concepts. He also stated there was a lot of higher order thinking involved, and felt being forced to analyze the data and "break it apart" made him feel like he truly "learned a lot".

Two students did not answer this question. Student eight reported being unable to recall how much she analyzed the data, and student four reported that he did not approach the activities with an expectation to spend much time thinking or analyzing the work. He stated that he was frustrated with his current degree program and eager to finish, and he was "simply in a get the right answer and move on and forget about it mode".

For synthesis, did you put data together into a larger whole? Were you able to "see the bigger picture", to make predictions or generalizations from the activities? Eight students also reported that synthesis was involved within each activity and that they made generalizations and predictions from the data. Student one explained by describing an activity in which they graphed a small amount of data, but then later were instructed to include more data into the graph. By doing this, they saw a "bigger picture" and this led them to different conclusions. Student three reported that some activities required using different data sources and synthesizing that data, “put it all together into like a whole, and then you make conclusions based upon the overlying concepts that you take from each individual part”. Student nine also reported that many of the activities involved making predictions into the future from the data and analysis.

Two students also noted that synthesis occurred within each activity, but also at later times in the semester. For example, student two described how the scientist she studied in the beginning of the semester played a large role in principles involved in the Snell’s law activity. When she did the Snell’s law activity, she said “it was kind of neat to see how it fit in with that bigger picture”. She further elaborated that the activities were placed in such a way that later activities built on previous work in activities. And student two mentioned also that the capstone project at the end of the course encouraged this, as well. She stated “as we were doing some of these activities, I was thinking ahead to the capstone and which of the activities I would pull to put together to make an interesting lesson plan”.

For evaluation, did you critique or judge any part of the activities, the data or your findings? Nine students reported that they critiqued or judged their data or some part of their work in the activities. Seven students reported that this occurred within each activity, and specifically, for four students, this was triggered by finding unexpected results. For example, student ten stated that for one of the activities, she knew what results were expected, and that her results were “a little off”. She stated, “I looked at it and like, what could’ve influenced that, critiquing what I did to see what I did, what I could’ve done differently, why it’s not matching up”. Student seven explained that in some cases, this unexpected result was exactly what the instructor wanted the students to see. She said, "one time, I found the exact information that she wanted, but I kept looking at it going this can't be because it can't be what she's asking us to do, and it was".

Two students reported critiquing the work without unexpected results. Student five mentioned that he evaluated and questioned data in the eruptions problem set where they were to relate ground movement to inflation or deflation events and possible impending eruptions. Student three reported that the activities, by design, encouraged deep thinking. He stated, "it wasn't just do the simple problem set and we'll kind of move on, you really spent a lot of time thinking through each part and going back to the original concepts and objectives".

Three students reported that this evaluation and critiquing occurred at later times than while working through the activities. One student, student three, stated that this occurred with the teaching and learning discussions, where:

> you took everything you learned and thought back and said okay how could I really incorporate this into *my* setting, can I use this open data source, can I use this activity, if not, what would you change, if so what are the parts that you would incorporate and how would you do it, so there was a lot of reflecting and critiquing, especially towards the end of each lesson.

Two students reported that they evaluated their work more when they received feedback in their graded activity worksheets. Student one stated that when she did something incorrect in her activity worksheet, the instructor provided feedback. This student, when reviewing her work, reported asking more questions about why she did something incorrectly, and the instructor would reply statements such as, "well, what if you did it this way, could you come to this conclusion". Student one stated that this helped her to reconsider and re-evaluate her work. Student ten reported a similar experience. For the optics lab, she stated that she made errors, but the instructor talked to her about it and made comments. With this feedback, she re-evaluated her work and, even without receiving a grade for it, corrected her work. She stated that she considered "what I did wrong and figured out how to do it correctly".

Main Questions Nine: What Role Did Any Problems Interacting with the Technology in the Course and in the Activities Have in Your Learning?

Nine students reported that they had very few, if any, problems using the technology in this course. Two students stated outright that the technology was not a problem, but eight students elaborated that it was due to the instructor's guidance and directions that helped the technology to be problem-free. Students one, two, and ten stated that the podcasts, written directions for both PC and Mac computer users, and the sequential lay-out of the directions made the technology easily usable and navigable. Student nine added that the instructor used a Mac, but she would access and use the technology she used in the course through a PC in order to write directions for PC users. Student seven stated that the instructor used the technology and software correctly, which made everything easier to use. Student three stated that if there were any problems, they could have just asked the instructor and she "would guide us in the right direction and you would find your way eventually".

Two students added that the guidance suited their characteristics or unique situation. Student two appreciated the guidance that was given because she was not a classroom teacher. She assumed that some of the classroom teachers in the course would have already been familiar with the drawing tools used in the course and therefore not need the directions, but she was appreciative of the directions being written at a level expecting no prior experience with the software and technology. She stated, “in order for me to be able to use it comfortably at home, I definitely was relying on that direction”. And, student eight described herself as a visual learner, and stated that the video clips showing the instructor modeling the actions the students would take to use the technology helped significantly.

Student five added that using the technology was by no means easy. He stated that most of the open data sources, technology, and agencies that host the data make reporting the data difficult. But, he stated:

> I thought it was an excellent level of difficultly, there were several times that using online data sets and real life field data and seismic data, it could be frustrating, but that was by no means a limiting factor, we would eventually work together as students or with the help of [the instructor] and solve it.

The cases of problems with the technology seemed to be unique circumstances or specific to the student and mentioned by only one student for each example. For example, student nine reported that he had an older computer which could not handle downloading the software programs. Student four stated that he had a long-standing issue with using Excel and found using it to be frustrating. Student eight reported having time limitations, due to caring for her children, which prevented her from investing time in learning new graphing programs. She stated that she would have her husband learn the programs and help her with using them. And, student one was in Hawaii when she took this course and this presented a couple of small, unique problems for her. For one, the time change meant that ANGEL was inaccessible at certain times when she was doing the coursework. And, in the summer 2012 class, there was a problem with the server for the Hawaiian Volcano Observatory. Student one reported frustration with being at the location, seeing the instruments working correctly, yet being inaccessible on the website.

In a question probing for more information, I asked the students about the learning management system, ANGEL. Five students reported that they had no problems with using ANGEL. But two students who were familiar with other learning management systems reported some frustration with ANGEL. Student three reported having experience with another learning management system and expressed frustration with the outdated, in comparison, schematics of ANGEL. Student six reported having experience with yet another learning management system and mentioned disapproval of the design for discussion forums in ANGEL and the way that threads are nested. She stated that it was difficult to view the discussion and took her some time to get used to it. But, she stated that it was "one of the reasons I think that the discussions, they're a little harder to have because they don't naturally necessarily flow in order somehow, so I just found it cumbersome".

Chapter 5

DISCUSSION, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Discussion of the Results and Interactions

Interviews with students, and analysis of the lab-type activities in this course provided evidence of the interactions that occurred in this course about the lab-type activities. Specifically, through the analysis of the learner-instructor, learner-learner and perceptions of learner-content interactions, this study provided a better understanding of the use of lab-type activity in an online geoscience course, and whether the use of lab-type activities can attain the goals of constructivist learning in the online environment. This section summarizes the results of this research and evidence of the interactions, and draws conclusions about the use of lab-type activities in this case of an online graduate geoscience course. Based on this study and findings, recommendations for implementation of lab activities in online geoscience courses and for further research are presented.

Learner-Instructor Interactions

Quality learner-instructor interactions consist of the instructor designing and structuring activities meant to promote meaningful learning, and facilitating the efforts through these activities (Anderson et al., 2001), including communicating expectations and guidelines, sharing or persona and empathy, and timely feedback (Dennen et al., 2007). The instructor designed this course and included detailed directions and guidance through the content and activities. Her screencasts and videos included her personal guidance though the learning. The instructor's feedback in the activities was specific, to-the-point, and she was very involved with the students' work. Students agreed that her feedback in the course was clear and detailed. Every part of the students' activities appeared to be analyzed by the instructor, she provided feedback for errors to show students how to arrive at the correct answer, and elaborated on answers that could have been expressed more accurately. This feedback showed, and was corroborated by students in interviews, the instructor facilitating and scaffolding the students to reach resolution with the activities and the correct procedures and answers. This is a critical element of constructivist learning and learning through lab-type activities, that the activities are student-centered with the teachers as facilitators to orient, guide and scaffold the learners through the learning process (Honebein, 1996; Wheatley 1991; Brooks & Brooks, 1999; Michael, 2006; von Glaserfeld, 1993).

Students reported having very few problems with the technology in the course and necessary for the lab-type activities. Problems reported seemed to be unique issues for the student, rather than class-wide problems reported by most of the students. Learner-technology interaction is an important interaction in distance education because students less proficient with a technology can encounter obstacles in learning in the online environment (Bray, Aoki, & Dlugosh, 2008; Cho, 2011; Hillman et al., 1994). But, the technology in this case did not appear to negatively affect the students' learning. Students reported that the instructor's proficiency with technology and sufficient guidance through using it prevented interaction with the technology in the course from being cumbersome or frustrating. Hillman et al. (1994) recommended that the technology in a distance course be modeled and students should be given practice opportunities to increase their proficiency with complex technology. In this case, it appears this was done sufficiently through the instructor's design of the course and assignments requiring practice with using plotting software, as well as screencasts modeling the technology, provided guidance that allowed students to use the technology successfully.

The instructor should also encourage learner-learner interaction through questioning aimed at promoting critical thinking (Marks et al., 2005). The Questions and Teaching and Learning discussion forums enabled interaction among students, but also with the instructor. The instructor reported using the Questions discussion forum as an outlet and resource for students to post questions related to any problems with the problem sets or for questions regarding doing calculations or quantitative work. She also reported using this resource to address questions that she expected everyone in the course might have had about something in particular; rather than responding to one e-mail, she could respond to the same question in the Questions discussion forum and others in the course could also benefit from the answer. In the Questions discussion forum, most students posted questions that appeared they were seeking help with calculations or explanations of content or activity tasks. The instructor was involved in the discussion, and her responses were characteristic of mentoring and scaffolding type responses meant to enable the students to complete the tasks successfully. She tried to facilitate the students to find the answers on their own by providing sufficient guidance but no answers, and this was corroborated by the fact that most students in the course offering in which a particular part of an activity was discussed had that part or those questions correct in their graded worksheets. It cannot be assumed that students in the course offering that did not participate in the discussion thread about a certain part or activity actually read the responses from the instructor and used it to correct their work, but everyone in that offering would have had access to the same feedback.

The instructor's participation was also very involved in this discussion and she made timely responses. She replied to almost every thread, and most often within hours or the next day. She stated in her interview that she sensed that the students wanted her guidance through these tasks, and she wanted to provide sufficient guidance to them. She said, "I don't want them to give up and think that this is why nobody likes science".

Learner-Learner Interaction

The instructor was more involved in the Questions discussion forum, but she took a more reserved role in the Teaching and Learning discussions, she reported to allow students to collaborate with each other and share resources and information; therefore, the Teaching and Learning discussion provided a better view of the learner-learner interactions. The instructor stated that she intended this discussion to be a resource for the students to reflect on the content and activities, and share ideas and resources with other Earth science teachers. She stated, "I think a lot of high school teachers can feel kind of isolated, they don't necessarily have a lot of colleagues who are feeling innovative or who have tried something". This is supported by students' comments in interviews that the Teaching and Learning discussions were useful for the collaboration and sharing of ideas for teaching and sharing resources, and even non-teachers reported that their perspectives were valuable contributions and added a different dynamic. The instructor acknowledged that she has no experience with teaching at the high school level, so she reported that she allowed the students to lead these discussions, and participated less than what was observed in the Questions discussion forum. This is supported by the greater number of student posts and replies in the Teaching and Learning discussion compared to in the Questions discussion forum.

More evidence of reflection was observed in the Teaching and Learning discussion where students discussed teaching and using the activities and content in teaching. In the discussion about activities in the Teaching and Learning discussion forums, seven students appeared to reflect on, and find meaningfulness in, the optics lab, and one student on the eruptions activity. Two students appeared to reflect on the Snell's law activity, and one on the eruptions activity. One student appeared to reflect on the eruptions activity and asked a question based on what I interpreted was his own curiosity. From student interviews, three students stated that the Teaching and Learning discussions increased their reflection about the activities. However, not every student appeared to reflect on each activity or find each activity meaningful in the Teaching and Learning discussions. Either there were no posts from some students, or students mentioned obstacles to use of the lab-type activities in terms of the math involved or difficulty fitting the activities into their curriculum, without any additional discussion of how they could overcome these obstacles and still make use of the activities. This was an unexpected result for two reasons. First, students reported in interviews that they found the activities meaningful. Second, research from Goodman et al. (2006) found that pre-service and in-service science teachers often feel unprepared to teach, or uncomfortable with teaching, science, due to having a limited background in science. But, Nilsson and van Driel (2011) and Goodman et al. (2006) found that content knowledge and attitudes toward teaching science can be improved for these students through problem-solving activities and interactions with more-knowledgeable others and peers. Based on this observation and research, I expected to observe reflection on the meaningfulness of the lab-type activities in the Teaching and Learning discussions in relation to almost every lab-type activity and from almost every student. I anticipated that the evidence of this would be nearly as abundant as what I observed, for example, for the instructor as facilitator and utilization of higher order thinking.

The goal of learner-learner interactions in constructivist learning is that students engage in discussion about activities and reflect on the activities through practicing the language of the discipline or culture (Tobin, 1998), and discussing content (Moore & Kearsley, 2005). Sringam and Greer (2000) further state that quality learner-learner interactions should involve constructing knowledge in a shared learning environment. Few posts overtly showing reflection is not reason to conclude that students did not reflect on the meaningfulness of the activities at the time they were participating in the course. Garrison and Cleveland-Innes (2005) stated that a lack of discussion does not mean that reflection did not occur. They stated that students can be engaged vicariously by following discussion and reflecting without posting explicit messages indicative of it. This is supported by students four and six who reported that they did in fact reflect on the activities before posting to the discussion, and they mentioned that they seemed to gain more from their own personal reflection than from the interaction in the discussion. Student six stated, “most of what I got out if it was thinking about what I wanted to say”.

But, what is evident of the learner-learner interactions in the discussions and from interviews is that, in this study, the learner-learner interactions appeared to be more reflective of students empathizing, sharing resources and experiences with each other. Students appeared to empathize over teaching, and if they discussed obstacles to using the activities in this discussion, their interaction about this showed empathy and support. They reported in interviews that the role of interaction with other students was for support and to compare work, and in the Teaching and Learning discussion, for collaboration and sharing ideas. This is supported by other researchers who have concluded that the value of learner-learner interaction is for building a sense of rapport and emotional support (Garrison & Cleveland-Innes, 2005), gaining advice, empathy and encouragement (O'Reilly & Newton, 2002), and a sense of community (Rovai, 2004). Results from this study appear more similar to learner-learner interactions for these reasons. Students may have approached the Teaching and Learning discussions as a supportive environment where they were comfortable sharing and empathizing with each other. The instructor agreed in her interview and stated that one purpose of the discussions was to connect teachers who might feel isolated from peers, especially other Earth science teachers.

There are several other possible reasons for this apparent lack of a significant amount of reflection on the meaningfulness of the lab-type activities in the Teaching and Learning discussion. The more open-ended nature of the directions for these discussions, for example, to reflect on lessons five and six, as opposed to specific questions posted to be discussed in the readings discussions about the readings, or asking the students to specifically reflect on the activities, may have been a reason. Furthermore, for the last Teaching and Learning discussion, it is not shown on the course page for lesson eight, like the other two lessons, that this discussion is graded. The lack of explicit reflection about the activities in the discussion may have been a result of the lack of specific guidance requiring it.

Furthermore, the amount of reflection might have been a result of the nature of the teaching or social presence in the discussion, that is, reflective discussion might have been inhibited by the instructor or the characteristics of the other students, or a combination of these factors. The classes of this course were all small, seven students or less, and interaction in discussions, especially among students, was influenced by characteristics of the students and size of the class. For example, in the smallest class, one student reported that the differences between the students in their different teaching states and progress through the Master of Education in Earth Science program inhibited discussion. The instructor agreed that the discussion depends on the number of students. She stated “if you only have about three as opposed to having seven, then it’s just a different kind of discussion”. For example, student eight was not teaching at the time and reported feeling like she could not contribute much to the discussion, but the discussion still gave her valuable ideas for how to use the activities when she does teach.

But, also, in two cases of the Teaching and Learning discussions, in two different offerings of this course, the instructor made the first, starting posts asking students about authentic data and a specific teaching methodology. This occurred in the first Teaching and Learning discussion in the spring 2013 offering, and the second Teaching and Learning discussion in the summer 2013 offering. There was only one post made by a student showing reflection and meaningfulness of an activity in his teaching in the spring 2013 discussion, and no posts showing this in the summer 2013 discussion. Furthermore, no posts were made to the third Teaching and Learning discussion in the summer 2013 offering. Student six from this offering stated that she did not find much value in the Teaching and Learning discussions because the instructor posted questions which sought concrete answers rather than encouraging expression of opinions. She stated that “there was a tendency to just answer the question, which I didn’t find that useful”. This is supported by Dennen (2005), who found that too much instructor presence and participation in asynchronous discussion forums can inhibit student participation. Or, it might have been in this study, that the instructor’s initial presence did not inhibit discussion, as there still was discussion among students, but rather, it directed it to particular topics and away from reflection about the activities. The class with the most students had discussion in the Teaching and Learning discussions showing the greatest amount of reflection and meaningfulness, but this offering also had no instances of the instructor starting the discussion.

Perceptions of Learner-Content Interaction

Higher order thinking. A goal of learner-content interaction is that it encourages higher order thinking, evidence of which has been cited as higher levels in in the cognitive domain of Bloom’s taxonomy of educational objectives (e.g. Bonwell & Eison, 1991; Dennen & Wieland, 2007; Garrison, Anderson & Archer, 2001; Sringam & Greer, 2000; Yuretich, 2003). Furthermore, effective labs should require higher-order thinking (Lumpe & Oliver, 1991), and reflection about the activity, as reflection is a component of the minds-on aspect of labs (Hofstein & Lunetta, 2004). Description and analysis of the questions and tasks in each activity provided a view of the nature of higher order thinking intended and showed that each activity, especially later activities, required it. Garrison, Anderson & Archer (2001) state that higher order thinking is probably best assessed through individual educational assignments, therefore, students' individual activity worksheets were evaluated to provide feedback as to how well the students performed on parts and questions that required higher order thinking. The majority of errors occurred with calculations, but most of the students were successful at questions in the activities, including the higher order thinking questions. This is supported by students' comments in interviews where most students reported that the activities required, and they used, higher order thinking. Most stated that analysis and synthesis occurred while doing the activity and four students stated that analysis led to synthesis of information. Nine students stated that they evaluated their work in the activities, and most reported that this was triggered by getting unexpected results. This is consistent with posts made to the Questions discussion forum, many of which were initiated due to a student receiving a result that they questioned. The instructor mentioned in her interview that she purposely includes certain questions and analyses that give students unexpected results. Furthermore, two students reported that synthesis occurred for them in the Teaching and Learning discussions, and when they received their graded work, which further encouraged reevaluation.

Blumenfeld et al. (1991) stated that effective problem-based learning should also involve students in the development of approaches to solve a problem. The lab-type activities also showed a progression through the course in terms of complexity, requiring students take more active roles in solving the problems. There is a progression from lower order to higher order thinking questions within each activity, higher amounts of higher order thinking questions in later activities, increasing use of open data sources, more complex levels of analysis of the data, and more reliance on students' decision making in presenting the data. This is consistent with the instructor's statement in her interview that her activities are designed from simpler to more complex, and she tries to model their analysis in the beginning so they can perform it on their own in the end. She stated that she "tried to build up their intuition a little bit", by having worksheets and fill-in-the-blank type questions and directions for making a plot, but in later activities, the instructor's approach is:

> here's the data, what is the best way to analyze if there's a relationship between these two things and should there be and how would you figure it out and in my mind, I'm hoping they make a plot, but I feel like, there's a point that you hope there's a leap they'll make on their own, having been led through it.

She stated by the end of the course:

> we're using a combination of seismic data and geodetic data to sort of come at the same kind of calculation from different ways, that's sort of the part where I hope they've figured out that there's more than one kind of data that you want to collect depending on what the time scale and aerial scale is of the problem you're working on and so where those kind of data sets overlap is an important thing to think about when you're solving a big problem with other stuff going on.

The instructor reported seeing "ah-ha" moments when the students use multiple sources of data and synthesize it with their prior knowledge into see a holistic picture.

Meaningfulness and authenticity. Effective labs involve meaningful activity and authentic problems and tasks (Hofstein & Lunetta, 2004), but several researchers have discussed variations in the notion of what authentic means. Brown, Collins and Duguid defined authentic activity as "ordinary practices of the culture" (1989, p. 34), and Herrington et al. state that "authentic activities mirror real-world tasks" (2004, p. 8). However, the lab-type activities used in this online geoscience course are not the exact reproductions of the procedures and actions of a geologist in this discipline. Some of the data and procedures used in these lab-type activities may have been authentic to the geosciences discipline, for example, the instructor stated that the data students worked with from the Hawaiian Volcano Observatory was the "same data that those guys work with when they are trying to characterize the state of the volcanoes and the system out there, the same kind of data that they would use if they were going to issue a warning and an eruption forecast". But, authentic practices of a discipline may not necessarily be authentic in the context of classroom instruction. Brown, Collins and Duguid stated that "when activities are transferred to the classroom, their context is inevitable transmuted; they become classroom tasks and part of the school culture" (1989, p. 34). And, Herrington et al. (2004) state that real-life experiences may not be translatable to educational settings, for example due to limitations in physical environment or safety reasons.

The purpose of the lab-type activities in this study were to provide the students with activities and resources to be adapted and used in teaching, and therefore were more authentic to teaching. Herrington, Reeves and Oliver state that in an authentic learning environment, "students become immersed in problem solving within realistic situations resembling the contexts where the knowledge they are acquiring will eventually be applied" (2006, p. 235). Brooks and Brooks (1999) also stress using real phenomena, tools, and primary sources of data. The instructor of this course stated that some of the data is older, more sanitized for use, or put online for educational purposes, but, she stated, it is real and valid. This use of real data appeared to have a positive effect on the lab-type activities, as students reported in interviews that they found the activities to be authentic and realistic. And, all of the students reported in interview that they also found the activities meaningful and saw a use for them in their teaching. Half of the students reported in interviews that they actually used some of the activities, with modification for the level of their students. Students also reported that the use of real data sources in the activities positively affected their interest in the activities, or added to the meaningfulness of the activities. This is consistent with Shiland's (1999) conclusion that application of an activity to real situations or use in real situations further adds to the meaningfulness of the activity.

Building on prior knowledge. Constructivism's view that learners construct knowledge through the filter of their prior knowledge and experiences requires that prior knowledge be utilized in learning, and effective labs utilize the experience and prior knowledge of the learner (Corter et al., 2007), and aid in the understanding of content (Bigler & Hanegan, 2011). Students reported in interviews that doing the activities aided their understanding, and the activities helped them to understand the "why" in the content, rather than approaching the content for just memorization or knowing concepts.

The new experiences and interaction with the content allowed for the understanding, and aided retention and recall of the information. This is consistent with researchers Bonwell and Sutherland (1996) and McConnell et al. (2003) who found that students are more likely to understand and remember content after using active learning approaches, and Dori and Belcher (2005) who found that active learning enhances conceptual understanding. Furthermore, the students' understanding was tied to the meaningfulness, and several students understood the activities through their reflection of how they could use it in their teaching. A few posts by the instructor in the Questions discussion forum showed evidence of trying to trigger students' prior knowledge. In interviews, most students stated that the activities aided their understanding of the content, either due to the in-depth interaction or the experience with real data This connection among authenticity, meaningfulness and understanding is consistent with Brown et al.'s (1989) observations in cognitive apprenticeships, where engagement in authentic activities adds meaningfulness and relevance of the activity, and aids in understanding, and Mayer's (2004) conclusion that cognitive activity promotes meaningful learning.

Conclusions

The purpose of this descriptive and exploratory qualitative case study was to explore whether the online environment and use of lab-type activities in a graduate online geoscience course can support learning as described in the constructivist view. The use of lab-type activities in this course appeared to achieve most of the goals of constructivist learning, and specifically:

- The learner-instructor interactions showed that the instructor of this course was a facilitator and guide for the students through the activities to scaffold them towards completing the activities with success.
- While students engaged in discussion, and some reflection occurred about the activities, in this study, most learner-learner interaction in discussion forums about the lab-type activities occurred for the purpose of comparison of results, support, and empathy.
- For the learner-content interactions, students reported that they used higher order thinking in their interaction with the lab-type activities, both within each activity, and progressively through the semester to more complex activities. Evidence from their success at higher order thinking type questions in the activities supports this. Students also found the activities realistic, meaningful and authentic, and this increased their interest with the activities. Students perceived that their interactions with the activities also aided their understanding of the content.

Recommendations

The results of this study suggest that the online environment can indeed support constructivist learning with lab-type activities in a graduate geoscience course. Several elements evident in this case provide useful recommendations for the use of lab activities in an online geoscience course. First, the amount of instructor presence appeared to have a large effect on the students' success with the lab-type activities. The presence was shown in the detailed directions, which were supplemented with videos where appropriate, the amount of participation the instructor showed in the discussion forums to guide the students towards successfully completing the activities, and in the feedback in their graded activity worksheets. This guidance was also reported by students to have been the reason why the students' interactions with the technology were not problematic. Therefore, it is recommended that the instructor of an online course utilizing lab-type activities show strong presence in the course. Directions for accessing open resources and gathering data from these resources should be explained in detail and modeled, when appropriate. The instructor should be involved in the discussions, asking students open-ended questions that further discussion or providing guidance that supplies enough information for students to be successful at the task without giving away answers, and participate in discussions in a timely matter, for example, every day. Feedback to students in graded labs should be specific throughout the worksheets, and point out exact places of any errors, but also supply constructive and positive feedback.

Students reported that they valued student-student interaction for support and empathizing, therefore, resources and outlets for this type of sharing should be included. But to attain the constructivist goal of having learners engage in knowledge-building discussion and to encourage students to engage more thoughtfully in their discussion with their peers about lab-type activities, the instructor should also require participation and discussion about specific aspects of the lab activities. The nature of in-depth, higher-order thinking type interactions could be modeled by the instructor in the beginning of the class with direction to the students to deliberately note the nature of this type of discussion, and then graded later in the semester by assessing the quality of this type of interaction the students' discussion with each other.

Last, students reported enthusiasm for the use of real data and open resources, and the deep interactions they had with the data to complete the activities. They reported that this increased their interest in these activities and the likelihood that they would use them in their own teaching. Therefore, lab activities in an online setting should use primary sources of data from real and open sources, and require in-depth interaction with the data to draw conclusions. The lab activities should end with questions that ask the students to synthesize and evaluate the information. Synthesis of the findings could be encouraged through questions that, for example, ask students to relate their analysis to the how it adds to the geosciences discipline, a larger phenomenon, or with the course content. And, evaluation of the findings could be encouraged through questions directing students to reflect critically on their work by, for example, finding sources of error or research or other sources of data that corroborate their findings.

Suggestions for Further Research

The results and conclusions drawn from this study have added to the sparse literature on lab-type activities in online geoscience courses, but many areas are still in need of further research, several specific areas of which are suggested from this study. Variations in the nature, characteristics and number of participants in a study of lab-type activities in an online geoscience course should be areas for further research. The students in this study were adult graduate students who were employed in a field to which content in this course was directly relevant, and this probably enhanced their motivation in the course. A study involving younger, and possibly unmotivated, students would further shed light on the use of similar lab-type activities in an online geoscience course.

The instructor was very involved and present in the course and discussions, and supportive to students both within and outside of the course. Students in interviews had nothing but positive comments about the instructor, and in fact, several students stated that the instructor was one of their best professors. The low enrollment in these offerings of the course may also have allowed the instructor to be more present and invest more time in providing individual, detailed feedback. Further research is needed for the use of lab-type activities in an online geoscience course directed by an instructor not as supportive, invested or facilitative, or a higher enrollment course in which the instructor may not be able to invest as much time providing feedback to individual students.

In terms of the specific lab-type activities, the optics lab was recalled most out of the six studied by students in interviews, and most students reflected on this activity and found meaningfulness in this activity in the Teaching and Learning discussion. One student stated why he preferred this activity: “I think it’s the hands-on aspect…I mean the kinesthetic, you got your hands on it”. Traditional hands-on labs have been considered the most difficult element to include in distance science courses (Ma & Nickerson, 2006), but the results of this study suggest that traditional hands-on labs in an online geoscience course are worth a closer look and more study.

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Appendix A – Student Informed Consent Form

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: Exploratory Qualitative Case Study of Lab-Type Activity Interactions in an Online Graduate Geoscience Course

Principal Investigator: Veronica Ciavarella, Graduate Student
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Williamsport, PA 17701
(570) 567-7413; vcc111@psu.edu

Advisor: Dr. Gary Kuhne
Adult Education Program
314E Keller Building
University Park, PA 16802
(814) 867-0228; gwk1@psu.edu

1. **Purpose of the Study:** The purpose of this research is to explore the use of lab-type activities in an online Earth science course in order to better understand the learning that occurs through the use of such activities. The activities utilized in this course are the focus of this study. This study is being conducted for Doctorate of Education dissertation research in Adult Education, specifically focusing on Distance Education, and the feasibility of conducting lab-type activities in distance science courses.

2. **Procedures to be followed:** Data for this study will be collected through two main methods. First, the principle investigator will either be present in your online course, but will not participate in any way, or will study the course in which you participated. I will be observing the discussion forums and the discussions you have, or had, with other students and the instructor about the activities, and any other relevant written communication that applies to your experience with the activities. To provide a better picture of your individual experience with the activities, I will also observe the assignments you submitted after completing the activities. Second, you will be asked to participate in a tape-recorded phone interview in which you will be asked twelve questions pertaining to your experience with the activities you completed in this course. Any communications or data not pertaining to the activities will not be collected, used or reported.

3. **Duration/Time:** The phone interview will require approximately 45 minutes to 1 hour of your time toward the end of summer, 2013. Nothing is required of you beyond the course requirements for the observation of discussion and assignment analysis portion of the study.

4. **Statement of Confidentiality:** Your participation in this research is confidential. The data will be stored and secured at the principle investigator's private, locked office in

a locked file cabinet or on a password-protected computer. All identities will be protected through the use of pseudonyms in the data analysis and presentation. Only the principle investigator will have access to your identity and access to the data. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

5. **Right to Ask Questions:** Please contact Veronica Ciavarella with questions or concerns about this study.

6. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to consent to take part in this research study. If you agree to take part in this research study and the information outlined above, please type your name and indicate the date below.

Please retain a copy of this form for your records.

Participant Signature	Date
Veronica C. Ciavarella	6/19/13
Person Obtaining Consent	Date

Appendix B – Instructor Informed Consent Form

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: Exploratory Qualitative Case Study of Lab-Type Activity Interactions in an Online Graduate Geoscience Course

Principal Investigator: Veronica Ciavarella, Graduate Student
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1. **Purpose of the Study:** The purpose of this research is to explore the use of lab-type activities in an online Earth science course in order to better understand the learning that occurs through the use of such activities. The activities utilized in this course are the focus of this study. This study is being conducted for Doctorate of Education dissertation research in Adult Education, specifically focusing on Distance Education, and the feasibility of conducting lab-type activities in distance science courses.

2. **Procedures to be followed:** Data for this study will be collected through two main methods. First, you will be asked to allow the principle investigator access to this course in ANGEL, so that I may observe the discussion forums and the discussions among students and that you have with students, and any other relevant written communication that applies to the students' experiences with the activities. To provide a better picture of students' individual experiences with the activities, I will also observe the assignments they submit after completing the activities. Description of the course and activities will also be provided in the study in order to provide the context and background of the activities. Second, you will be asked to participate in a tape-recorded phone interview in which you will be asked six questions pertaining to your use of activities in this course. Any communications or data not pertaining to the activities will not be collected, used or reported.

3. **Duration/Time:** The phone interview will require approximately 45 minutes to 1 hour of your time toward the end of April or beginning of May, 2013.

4. **Statement of Confidentiality:** Your participation in this research is confidential. The data will be stored and secured at the principle investigator's private, locked office in a locked file cabinet or on a password-protected computer. All identities will be

protected through the use of pseudonyms in the data analysis and presentation. Only the principle investigator will have access to identities and access to the data. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

5. **Right to Ask Questions:** Please contact Veronica Ciavarella with questions or concerns about this study.

6. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to consent to take part in this research study. If you agree to take part in this research study and the information outlined above, please type your name and indicate the date below.

Please retain a copy of this form for your records.

Participant Signature	Date
Veronica C. Ciavarella Person Obtaining Consent	1/7/13 Date

Appendix C – Interview Questions

Student Interview Questions

Background Questions

1. What is your teaching experience?
2. What is your experience with distance courses? How many courses have you taken in this program? With the instructor?
3. How well do you know other students in the course? How comfortable are you with interacting with them? Do you communicate with anyone outside of the course?

Main Interview Questions

1. What was the role of the activities in your learning?
2. How was the instructor's guidance through the activities (both written directions and feedback in discussion forums) in your learning?
3. What was the role of interacting with other students in your learning from the activities?
4. How well did doing the activities aid in your understanding of the content? Are there concepts that you understand better now than you did before the course?
5. How meaningful were the activities to you, meaning, do you see a use for them in your own teaching? How likely are you to use them in your own teaching?
6. How do you view the authenticity of the activities, meaning, how reflective do you think the activities are of actual scientific practice? How did this affect your perceptions of the activities?

7. How did the “Teaching and Learning Discussion” affect your perceptions of the activities?
8. How deeply would you say that you interacted with content in the activities? More specifically in terms of levels of higher order thinking:
    a. (For analysis) Did you break information or data in the activities down into smaller pieces, or make connections among disconnected pieces of data?
    b. (For synthesis) Did you put data together into a larger whole? Were you able to “see the bigger picture”, to make predictions or generalizations from the activities?
    c. (For evaluation) Did you critique or judge any part of the activities, the data or your findings?
9. What role did problems interacting with the technology in the course and in the activities have in your learning?

Instructor Interview Questions

1. Why do you include these activities? What is your purpose for them?
2. How would you describe your role as the instructor of this course?
3. What is your purpose for requiring students participate in discussion with each other? In the “Teaching and Learning Discussion”?
4. How would you describe your teaching philosophy?
5. How authentic are the activities, meaning, how reflective are they of actual scientific practice?

6. How would you describe the quality of the students' work with the activities? Do you find evidence of higher order thinking, specifically:
   a. For analysis, how well do students break information or data in the activities down into smaller pieces, or make connections among disconnected pieces of data?
   b. For synthesis, how well do students put data together into a larger picture? Are they able to "see the bigger picture", to make predictions or generalizations from the activities?
   c. For evaluation, how well do students judge the activities? Do they critique any part of the activities, their data or findings?

Appendix D – Analytical Framework for Cognitive Engagement in Discussion from Zhu (2006)

Category	Characteristics	Example
Question	Seeking information	Question that has a direct and correct answer (e.g., What is an asynchronous discussion?)
	Inquiring or starting discussion	Question that has no direct and correct answer. (e.g., How can we facilitate an online discussion?)
Statement	Responding	Statement that is made in direct response to a previous message(s), offering feedback, opinion, etc.
	Informative	Statement that provides information (anecdotal or personal) related to the topic under discussion.
	Explanatory	Statement that presents factual information with limited personal opinions to explain related readings or messages.
	Analytical	Statement that offers analytical opinions about responding messages or related reading materials.
	Synthesizing	Statement that summarizes or attempts to provide a summary of discussion messages and related reading materials.
	Evaluative	Statement that offers evaluative or judgmental opinions of key points in the discussion/related readings.
Reflection	Reflective of changes	Statement that reflects on changes in personal opinions and behaviors.
	Reflective of using cognitive strategies	Statement that explains or reflects on one's use of cognitive strategies/skills in accomplishing certain learning tasks.
Mentoring	Mentoring	Statement that explains or shows how the understanding of a particular concept (idea, etc.) is reached.
Scaffolding	Scaffolding	Statement that guides students in discussing concepts and in learning content materials by offering suggestions.

Appendix E – Document Analysis and Observation Guide

Meaningfulness

Meaningful will be used in this study to refer to knowledge that is purposefully connected to one's existing knowledge, and that has importance, use, and fit in a larger pattern (Ausubel, 1961). In this study, because the students are practicing teachers taking a course in teacher education, meaningfulness will refer to the use, utility and applicability of activity to their own practice of teaching and in their understanding of content they teach. *In learner-learner, learner-instructor, and students' perceptions of learner-content interactions, what evidence supports that students find the knowledge meaningful, i.e., do the students relate the content to their teaching, find utility in their own teaching?*

Authenticity

Authentic activity has been defined as "ordinary practices of the culture" (Brown, Collins & Duguid, 1989, p. 34). Authentic activity adds meaningfulness and relevance of the activity, and aids in understanding. To apply this to the culture or nature of science then means that authentic scientific activity or inquiry refers to doing science in a manner that mirrors actual practice of science by scientific communities (Hume, 2009). Hofstein and Lunetta (2004) also refer to authentic scientific practice as having students "investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science" (p. 30) For authenticity in problem-based learning, problems should be tied to real life phenomena and contexts with real-life complexity, and should involve the ordinary practices and tools of the culture and professionals, including using primary sources of data (Brooks & Brooks, 1999). For science learning and in this study, authentic activity refers to doing science in a manner that resembles the practice of science done by scientific communities (Hume, 2009), which includes using real phenomena, tools, and primary sources of data (Brooks & Brooks, 1999). *In the learner-learner, learner-instructor and students' perceptions of the learner-content interactions, what evidence supports that students view the activities as authentic?*

Social Interaction and Reflection

Constructivist approaches utilize social interaction and collaboration between teacher and students and among students (Honebein, 1996; Jonassen et al., 1995). This interaction should involve discussion and making meaning of the content through practicing the language of the discipline or culture (Tobin, 1998), Jonassen et al. stated that "constructivist environments engage learners in knowledge construction through collaborative activities that embed learning in a meaningful context and through reflection on what has been learned through conversation with other learners" (1995, p. 11). Reflection is a major part of the meaning making process in constructivism that can enhance understanding. Reflection most simply refers to thinking about one's actions or thinking (Russell, 1993), and involves deliberate "elaboration and application of one's learning", which can include the use of the content, the reason for the activity or parts of the activity, the applicability to other situations, etc. (Hofstein & Lunetta, 2004, p. 32). *In the learner-learner, learner-instructor and students' perceptions of learner-*

content interactions, what evidence supports that students engage in quality discussion and reflection over the lab-type activities?

Utilization of Prior Knowledge and Confrontation of Misconceptions

In science learning, individuals may come into instruction with pre-existing conceptions that may be misconceptions, naïve conceptions or alternative conceptions, and which are at odds with scientific concepts and phenomena (Posner, Strike, Hewson & Gertzog, 1982). Learning science then has been viewed by Posner et al. as conceptual change, which is the process of acquiring new or alternative scientific conceptions by replacing preconceptions with scientifically valid conceptions that are incompatible with the old conceptions. Constructivist teaching involves helping students to utilize their prior understandings and reorganize them through activity in their current experience (Tam, 2000), and to evaluate rational options and thoughts and address misconceptions or alternative conceptions (Karagiorgi & Symeou, 2005). *In the learner-learner, learner-instructor, and students' perceptions of learner-content interactions, what evidence supports that the lab-type activities are building on students' prior knowledge and allowing for the confrontation of misconceptions?*

Student-centered with Instructor as Facilitator

According to constructivism, learners actively construct their knowledge, rather than passively absorbing what is provided by the teacher, therefore learning in this paradigm is student-centered, such that the teacher's role has shifted to that of tutor, guide, facilitator and co-collaborator to aid students in their knowledge construction.

Facilitation in terms of distance education has been defined as an "assisting, guiding approach ('guide-on-the-side') to teaching" which "can be contrasted to the directive teacher-instructor ('sage-on-the-stage') approach" (Moore & Kearsley, 2005, p, 325). Similar to facilitation, scaffolding refers to guidance provided by a more capable or more knowledgeable person (Roth, 1993). With scaffolding, an individual is able to succeed at a task or gain understanding of something that the individual would have otherwise not succeeded at without the help of the facilitator (Shiland, 1999). More specifically, the teacher helps students to utilize prior knowledge to make preconceptions and misconceptions explicit (Hacker & Harris, 1992; Morris, 2002), and provides sufficient support and guidance through the learning or activity such that the individual invests effort, but is also able to succeed at the learning experience (Shiland, 1999). *In the learner-instructor interactions, what evidence supports that the teacher is facilitator scaffolding students to deeper understanding?*

Higher-order Thinking

In this study, higher-order thinking will be defined as the three highest levels in the cognitive domain of Bloom's taxonomy of educational objectives. The cognitive domain of Bloom's taxonomy classifies cognitive learning into six levels, which are, from lower-level to higher-level thinking, knowledge, comprehension, application, analysis, synthesis and evaluation. Analysis, synthesis, and evaluation are considered higher-order thinking attributes (Bloom, 1956). *In the learner-learner, learner-instructor and students' perceptions of learner-content interactions, what evidence supports that* *students are analyzing, synthesizing and evaluating the content in their interactions with the lab-type activities?*

Vita

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EDUCATION

D.Ed. in Adult Education, Pennsylvania State University, 2008-2014

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PUBLICATIONS, PRESENTATIONS

Ciavarella, V. C. and Wyld, S. J., 2008, Wall rocks as recorders of multiple pluton emplacement mechanisms – Examples from Cretaceous intrusions of northwest Nevada, in Wright, J.E., and Shervais, J.W., eds., *Ophioloites, Arcs and Batholiths: A Tribute to Cliff Hopson*: Geological Society of America Special Paper 438, p. 517-550.

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