A COMPARISON OF LEARNING:

INTEGRATION OF A VIRTUAL AND TRADITIONAL FIELD TRIP INTO AN INTRODUCTORY ENVIRONMENTAL GEOLOGY COURSE.

by

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ABSTRACT

Field trips are a common component of geoscience courses. However, time and budget constraints, increased safety considerations and large class size have become common obstacles to teaching in the field. Technology has provided an attractive alternative through the virtual field trip. While there is a wealth of virtual field trips available on the internet, it is unclear how students learn on a virtual field trip and how those trips are best incorporated in Earth Science curriculum. The goals of this study are to establish the learning goals addressed by virtual field trips, determine if virtual field trips are best used as a pre- or post-activity in conjunction with a traditional field trip and provide suggestions for developing effective virtual field trips. A groundwater hydrology and policy virtual field trip was developed and compared to a traditional field-based counterpart. The field trip was designed to help students gain an understanding of groundwater flow and aquifer properties, understand how geology influences the groundwater availability, learn how to use and evaluate data, develop question-asking and hypothesis-testing skills, develop observational and spatial reasoning skills, and gain an appreciation for the complexity of science and its application to real-world problems. A modified pre-test/post-test and attitude study was conducted to determine the effectiveness of virtual field trips, gain insight into how they are best used in an introductory Earth Science course and explore students' attitude toward virtual field trips. Students' performance, confidence, knowledge and attitude were evaluated prior to and following, the virtual and traditional field trips. The virtual field trip did not successfully mimic teaching observation and data evaluation learning goals; however it was able to address question and hypothesis posing skills and establish an appreciation for the complexity of a scientific issue. The virtual field trip in this study was best used as a pre-activity, it helped reduce novelty space and establish necessary content knowledge prior to going to the field. However, using the virtual field trip as a pre-activity may diminish students' sense of discovery and wonder about the natural world.

CHAPTER ONE

INTRODUCTION

Problem

The outdoor field experience has traditionally been an important component in Earth Science curricula (Keller, 1963; Folkomer, 1981; McKenzie et al., 1986). However, time and budget constraints, increased safety procedures and liability, increased classroom assessment requirements, environmental constraints, restricted access to instructive and accessible field sites and increasing class size (Rooney, 2002) are forcing geology instructors to find alternative means to provide students with a realistic field experience without leaving the classroom (Smith, 1996, Curry and Burton, 2002). Advancing computer technology has provided an attractive alternative to traditional field experiences, the virtual field trip. For the purpose of this study, a traditional field trip is a learning experience which takes place at a specific destination outside the classroom. While there is a wealth of virtual field trips available on the World Wide Web, it is unclear how virtual field trips are best used in the Earth Science curriculum. Very little research has been conducted to establish the advantages and disadvantages of using virtual field trips (Bellam and Scheurman, 1998; Hurst, 1998; Dunning et al., 2000; Nix, 2001; Spicer and Stratford, 2001) especially for the Earth Sciences.

The goal of this study is to assess the value and best possible role of virtual field trips in Earth Science curriculum and provide suggestions for developing and teaching with virtual field trips. The study addresses whether virtual field trips achieve the same learning goals expected from traditional field trips, and examines whether virtual field trips are best used as a pre or post activity in conjunction with a traditional trip. As virtual field trips become more common (Nix, 2001), it is necessary to establish an understanding of the value of virtual field trips as learning activities.

Review of Literature

There is a growing body of regarding human cognition and how people learn suggests students spend a considerable amount of time to learn complex subjects and solve problems they find interesting. Use of knowledge, creation of products and benefit to others are particularly motivating activities for students (Bransford et al., 2000). While students can be motivated by complex subjects, use of knowledge and the applicability of the information they are learning, students must also be supported in their learning. Students must develop a strong foundation of factual knowledge and an understanding of those facts before they can develop the ability to use that information in an inquiry-based environment (Bransford et al., 2000). Field trips as well as computer-assisted learning environments can provide a learning circumstance where students are presented with motivating activities that can help them develop factual knowledge and an activity to which to apply that factual knowledge.

Field trips are a powerful method of learning in any science, especially in the geosciences. Field trip’s focus on problem solving, use of knowledge and interest associated with learning in the field make them ideal modes of teaching science. Students achieve more advanced comprehension, application, analysis and synthesis when participating in field trips (Kern and Carpenter 1986, Orion 1989, Orion and

Hofstein, 1991; 1994, Gill, 1997). Outdoor, field-oriented activities in earth science courses strongly enhance the students' motivation and comprehension of the subject matter (Kern and Carpenter, 1986). Field trips are used to bridge knowledge throughout a course and pose 'what', 'how' and 'when' questions discussed in lecture (Orion, 1989). Field trips provide students with a real world experience allowing them to make unique discoveries and independent decisions from a scientific perspective. Students learn to make observations, record data, create working hypotheses and combine observations with additional research in the literature to solve problems brought to light through the field trip experience (Dunning et al., 2000).

Beyond the fact-based knowledge and skill development, students value and enjoy field trips. In particular, they enjoy learning in a realistic setting, developing subject knowledge, acquiring technical, transferable and holistic skills and collaborating with peers and lecturers (Gaskin, 2003). Even non-science students enjoy scientific field trips. They develop better concept of self, develop skills and discipline for constructive use of time and develop a systems approach to view nature (Lopushinsky and Besaw, 1986). Earth *systems* science views Earth as a synergistic physical system of interrelated phenomenon governed by complex processes involving the atmosphere, geosphere, hydrosphere and biosphere (USRA, 2003). An extraordinary field-trip experience allows students to take an active role in their education (Karabinos et. al, 1992) and, for some, can lead into a career in geosciences. However, due to large class sizes, safety considerations and cost, many introductory Earth Science students never have an opportunity to participate in traditional field trips. Virtual field trips provide an opportunity for students to ‘experience’ field geology with little post-development cost to their college or university. Virtual field trips offer a chance for a wide variety of students to experience geology in the field without having to leave the classroom. Students with disabilities may not be able to participate in traditional field trips; however, a virtual field trip provides them with the opportunity to experience the most ‘real’ field geology they are able to participate in (Cooke et al., 1997). Students who attend classes in low income school districts, budget-challenged universities or the inner city schools may never have the opportunity to get off campus and experience geology in the real world. However, a virtual field trip can provide them with such an experience. Schools located in areas that experience adverse winter weather or lack of functional outcrops may also struggle to provide a valuable outdoor field experience to their students during the regular school year. A virtual field trip can take a student from Western Illinois State, a college more than 6 hours away from a “good” outcrop (Melim, 2003) and give them a chance to visit Yellowstone National Park without leaving the laboratory.

Virtual field trips have the potential to appeal to many different learning styles and mastery speeds. On the internet, students can review the material much more easily than traditional field trips. The accessible nature of a virtual field trip may allow students with a low aptitude for learning in a field setting the chance to master the subject at a different learning rate (Eby et al., 2002). Virtual field trips can also provide an opportunity for instructors to use imbedded assessments which allow for more direct and less invasive monitoring of students’ progress throughout the learning process. Traditional field trips require a significant amount of planning, preparation (Orion, 1989;

1993) and out-of-classroom time that may exclude students in a variety of situations, such as students with families and working students. However, virtual field trips are normally considered inexpensive, they offer a student-centered approach to teaching and allow all students to view places which may not otherwise be viewed in a traditional classroom activity or textbook (Lacina, 2004). While utilizing a virtual field trip may not be an ideal field option for geology instructors, in some cases it may be the *only* opportunity to expose their students to geoscience in the 'field.'

Virtual field trip technology can range from full immersion virtual reality (e.g. Geowall, 2004) to photo guides through an area of interest (e.g. Windows into Wonderland, YNP, 2004) and comprehensive suites of interactive materials such as maps, photographs and manipulative diagrams (Reynolds, 2004). "Virtual field trips are computer-generated environments that offer media-rich interactions with a particular location, such as laboratories, museums, parks, zoos, even other countries," Stevenson (2001, p. 1). Whatever the mode, virtual field trips have several advantages and disadvantages. Geoscience is considered a highly sensitive (meaning it requires the use of many senses) science. Arguably it may be difficult for simple virtual field trips to capture the sensory essence of the science. Some believe by ignoring the senses in geoscience, we rob ourselves of the many dimensions of information and we diminish the potential richness of the field experience (Pestrong, 2000). Students improve their understanding about science while on field trips (Compiani and Carneiro, 1996); immersion in the field can helps students understand the full scope of problems and the complexity of the natural world. On the other hand, if a virtual field trip is able to elicit curiosity and intrinsically motivate as well as engage students in multiple modes of learning and exploration during the learning process, then virtual field trips are able to touch on the major theoretical themes of informal learning (Brody and Tomkiewicz., 2002). Edelson (2001) argues that technology, by design, can support the integration of content and process increasing students' experience with authentic activities while achieving deeper content understanding. Such technology can foster motivation by creating a demand for knowledge and eliciting curiosity; construct knowledge by allowing students to observe and communicate; as well as refine knowledge through reflection and application.

Virtual field trips are becoming more prevalent in Earth Science classrooms and are readily available on the World Wide Web. A Google search of *geology virtual field trip* yielded over 19,600 hits (Google, 2003). However, many geology instructors are reluctant to eliminate traditional field experiences, an essential component to geoscience education (Keller, 1963, Cooray, 1991). Research of field trip success suggests students need ample preliminary instruction to succeed in the field (Falk et al., 1978; Orion and Hofstein, 1991; Orion, 1993, Orion and Hofstein, 1994). Virtual field trips may provide a very effective mode of reducing novelty space and enhancing students' learning experience in the field. Novelty space consists of three factors that influence students experience in the field, cognitive factors, geographic factors and psychological factors. All factors must be reduced through adequate preparation to make students comfortable and able to learn in the field (Orion and Hofstein, 1994).

An effective and valuable virtual field trip should be usable, motivate a student to learn, provide them with enough information to be comfortable in the ‘field’ and give them the opportunity to develop similar skills and knowledge as in a traditional field trip (Orion, 1993; Edelson, 2001). In a technologically advanced world, an effective virtual field trip will reflect these factors and will be organized in an accessible, flowing, aesthetic manner. A virtual field trip may help students develop an understanding and appreciation for concepts through the scientific process (Nix, 2001) as they would on a traditional field trip. The actual website should work to showcase the trip’s context in the best light. The page should be readable, fast loading, clear, uncluttered and fully functioning (Smart Webby, 2003; Dreamink, 2003). Effective virtual field trips combine successful educational factors and web design factors to create a virtual field experience that is motivating, unique, accessible and interesting.

Virtual field trips have the potential to be powerful tools in Earth Science curriculum; however little in depth research has been completed to quantitatively validate the learning value of virtual trips. Preliminary, predominantly anecdotal, research suggests that students are extremely positive about the potential of virtual field trips to provide valuable learning experiences but are also insistent that virtual field trips should not replace traditional field trips (Spicer and Stratford, 2001). Hurst (1998) presented students with a series of case study virtual field trips and surveyed laboratory instructors and students regarding the benefits and disadvantages associated with virtual field trips. Qualitative results suggest that students benefited from simple computer interfaces however, the computers did not have the power or intelligence to fully replicate human interaction. While many researchers have suggested quantitative evaluations of virtual field trips, only anecdotal evidence suggests that learning can occur on a virtual field trips and students are receptive to learning in such an environment. This study will provide a quantitative assessment of the efficacy of virtual field trip in the Earth Science curriculum.

While there is some information regarding the creation of effective traditional field trips and student and instructor attitudes toward virtual field trip, they remain an enigmatic teaching tool in Earth Science. This study will answer the question: *What is the value and optimal role of virtual field trips in the Earth Science curriculum?* Specifically this study will address questions related to the design of the Water Wars virtual field trip, learning goals addressed by virtual field trips, the best possible use of virtual field trips in the Earth Science curriculum (Table 1).

Table 1: Hypotheses examined in this study

1. Students learned as much from virtual field trips as from traditional field trips.
2. Virtual field trips can equally address the learning goals expected from traditional field trips.
    a. Students learn the same observation skills on a virtual field trip as they would on a traditional field trip
    b. Students learn the same question asking skills and hypotheses on a virtual field trip as they would on a traditional field trip.
    c. Students learn to evaluate and use data on virtual field trips as they would on a traditional field trip.
    d. Students can develop an equal appreciation for the complexity of scientific issues and the natural world as they would on a traditional field trip.
3. Students are more confident following a virtual field trip activity than following a traditional field trip.
4. The virtual field trip is more effective as a pre-activity than as a post-activity when used in conjunction with a traditional field trip.
    a. Students have a better understanding of the entire issue using the virtual field trip as a pre-activity.
    b. Students develop more confidence in their understanding of the issue using the virtual field trip as a pre-activity.
5. The Water Wars virtual field trip is an accessible and comprehensible virtual field trip.

Water Wars Field Trip

The Winchester Development company proposed a 3,000 acre "Day Ranch" development west of the Gallatin River, in Gallatin County west of Bozeman, Montana (Figure 1). The development area consists of three main rock types, Archean crystalline basement unconformably overlain by Tertiary basin fill and modern alluvial deposits along the West Gallatin River system. The Archean crystalline basement, in the field trip area granitic gneiss, is considered a fractured potential, poor aquifer when fractures are numerous and connected. Tertiary basin fill, typically lenticular gravel, sand, silt and clay, has variable fair to good water yields and is considered an adequate aquifer for light irrigation and stock use (Dixon and Custer, 2002). The two units are separated by an unconformity which is visible in the field trip area (Figure 2). The nature (i.e. angular, non-, etc.) of the unconformity is unknown. Because of the geology of the area, the Day Ranch was unable to drill an on-site well capable of producing the massive amount of water needed to maintain a golf course. A test well was drilled on the valley floor which was able to pump enough water to irrigate the course, yet landowners were concerned the well could violate historic water rights held on Fish Creek, a tributary to the Gallatin River. Other concerns exist as well; the physical separation from towns and existing development, increased traffic and displacement of agricultural production and consumption of important wildlife habitat (GYC, 2001) are threats identified in the Day Ranch controversy.

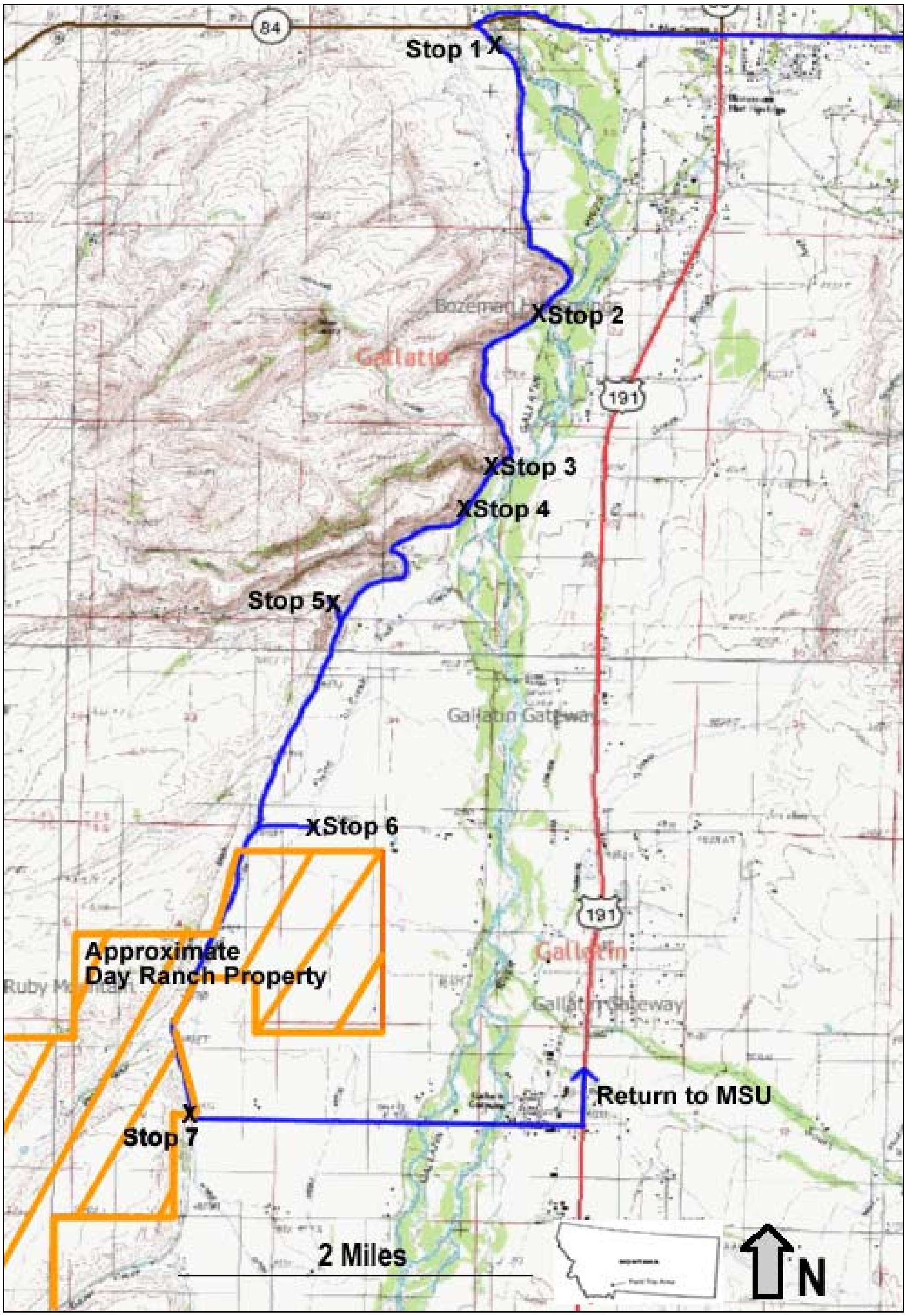
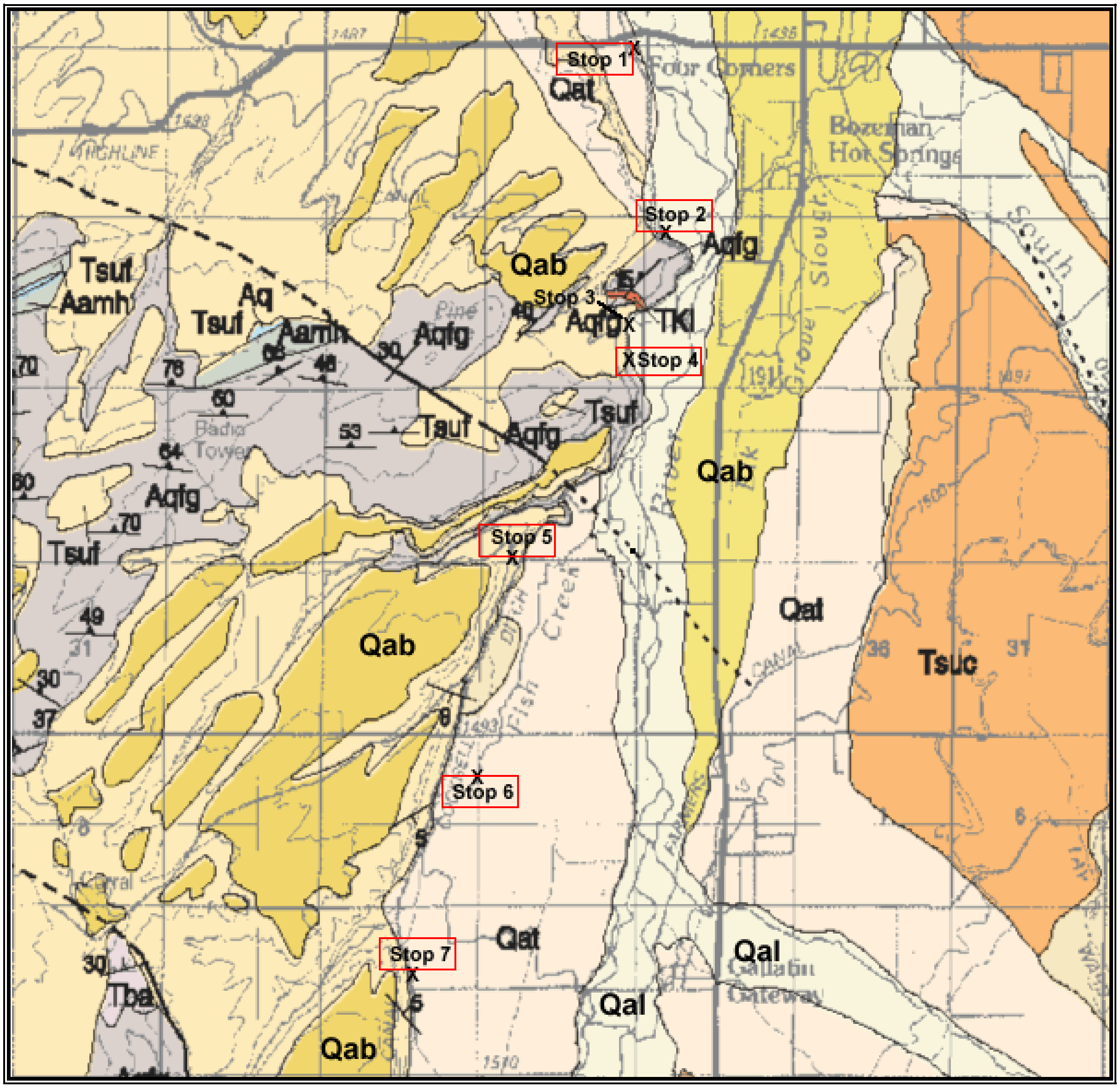


Figure 1- Location map for field trip (adapted from Topozone II, 2004)



KEY:

Qal	Alluvium of modern channel	Tsuc	Sediment or sedimentary rock, upper Tertiary coarser
Qab	Alluvium of braids	Tba	Basalt
Qat	Alluvium of alluvial terrace	TKl	Latite
QTgr	Gravel	Aamh	Amphibolites& hornblende gneiss
Tsuf	Sediment or sedimentary rock, upper Tertiary finer	Aqfg	Quartzofeldspathic gneiss
Tsuc	Sediment or sedimentary rock, upper Tertiary coarser	Aq	Quartzite

Figure 2. Modified geologic map of the field trip area (modified from Vuke et al., 2002)

In May of 2001, Winchester Development Company pitched the idea of the Day Ranch to Gallatin County residents. They asserted their development would not change the way of life in the county and would consider the surrounding residents and environment in the development plan (Gevock, 2001a). By June of 2001, the Gallatin County Planning Board made a decision to reject the developer's plan, citing "water was pretty key" in their decision (Gevock, 2001b). The possibility of violating long standing water rights, pumping water from a known aquifer uphill to a less well understood geohydrologic environment and inconclusive hydrologic tests and differing interpretations from developers and landowners were some major concerns to residents and the county. Winchester followed the rejection by filing suit against the Gallatin County Commission, stating the county acted arbitrarily when it cited goals in its master plan as rational for denying the subdivision (GYC, 2001). The Day Ranch developers applied to the state for well permits which were disputed at the state level for nearly two years. One week prior to the field trip experience, the Winchester Development company chose to pull their permit and cease development of the Day Ranch golf course ending the two year dispute (Gevock, 2004a). Shortly after completion of the field trip experience, the Winchester Developers settled their lawsuit brought against Gallatin County for $10,000, a fraction of the $11 million which they were asking (Gevock, 2004b). The field trip experience focuses on the geologic and hydrologic data, lines of evidence and arguments used in the Day Ranch controversy.

CHAPTER TWO

METHODS

This study examines traditional and virtual field trips as learning tools in an introductory Earth Science classroom. A virtual and traditional field trip to the proposed Winchester Day Ranch (referred to as the Day Ranch) was developed for an introductory Environmental Geology course (GEOL 102), with no prerequisites, in the Department of Earth Sciences, Montana State University.

Field Trip Design

This field trip was developed following Orion's (1993) *Model for the development and implementation of field trips as an integral part of the science curriculum.* The field trip is process oriented and uses concrete interactions between students and environment. Students are asked to role-play as geohydrology consultants, make and record observations, answer and develop questions and collect and evaluate data. The role-playing aspect not only provides an interesting and exciting environment for learning, it also challenges students to deal with complex real world problems and emphasizes the connection between science and daily life (SERC, 2004).

The Water Wars field trip experience is based on a local groundwater controversy that is centered around geologic, hydrologic and policy concepts. The field trip experience requires students to investigate the issues surrounding the proposal of the 3,000 acre subdivision and golf course, Day Ranch. The virtual and traditional field trips consider the environmental and geohydrologic implications of developing the Day Ranch subdivision and golf course. Each field trip consists of seven stops that emphasize individual components of the controversy; geology, surface hydrology, geologic controls on groundwater and policy involved in the case. Students are asked a series of questions to guide them through the scientific process and evaluation of the area's land-use and development potential (Appendix A). Students are expected to address the problem using an Earth Systems approach and discuss the geologic, hydrologic and political issues surrounding the question; "what are the land-use and development implications of development of the Day Ranch subdivision and golf course?" On the field trips, students role-play as geologists hired to evaluate the area and ultimately formulate an argument for or against the development of the subdivision. Both virtual and traditional field trips address objectives typically associated with learning in the field such as observation skills, spatial reasoning, evaluation and use of data and building an appreciation for the complexity of the natural world.

Students spend one two-hour laboratory session preparing for the field trips (virtual and traditional) and two seventy-minute lecture periods discussing ground and surface water processes and use. A groundwater investigation laboratory served as preparation for the field trip experience. Students assemble in groups of 8 individuals and investigate groundwater movement and contamination with plasticene models. The model allows students to explore and discuss how groundwater flow is influenced by rivers, recharge areas and rock type as well as how contamination moves through different materials in a heterogeneous groundwater system. The seventy-minute lectures cover the water cycle, groundwater storage and recharge, well use, contamination, surface water distribution, wetlands and surface water pollution.

The traditional field trip has seven observational and data gathering stops near the proposed Day Ranch subdivision. Students have roughly 15 to 30 minutes at each stop to complete a variety of tasks. All stops have specific learning goals and tasks which are clearly explained in the field trip guide (Appendix A) and discussed in the field. Students are expected to record any data, field notes or information necessary to complete their final reports, answer specific questions and participate in data collection.

The virtual field trip (http://gemini.oscs.montana.edu/~geol102/spring2004/Field%20Trip%20Stuff/Webpages/WATER%20WARS.HTML) leads students through a similar virtual field experience. The introductory information contains links to background information as well as questions and objectives students are to address during field trip. The road log follows the traditional field trip which highlights relevant geologic features and asks the same questions as those asked in the field. Upon “arriving” at the various stops, students are required to make sketches, describe rocks and make observations using photographs and illustrations displayed on the screen (Figure 3). With digital images, electronic data, geologic maps and cross-sections, students are able to record data, field notes and necessary information to complete their final reports. The fact that the virtual field trip does not include any enhanced virtual reality technology (such as 3D graphics, animations or flight simulator-type graphics) was a decision made in order to ensure fair comparison between the virtual and traditional field trips.

Figure 3- Clickable images in virtual field trip. Students roll the mouse over image on main page and can click to find more detailed, annotated and close up views of outcrops (Cantwell, 2003).

Sample Population

Montana State University is a land grant university established in 1893. The roughly 12,000 students are predominantly Caucasian undergraduates from Montana (67% MT, 33% other; MSU, 2004). This study was conducted in Environmental Geology (GEOL 102), an introductory geology course that fulfills the Contemporary Issues in Science Core (CISC) requirement. CISC courses “focus on natural science or technology and examine the ways in which science contributes to the study of significant problems in the contemporary world and can help individuals and society make informed decisions on these issues” (MSU, 2004). The Environmental Geology course concentrates on application of geologic principles to topical problems in environmental and resource geology. Specific topics include earthquake and volcanic hazards, mass wasting hazards, and weather hazards, petroleum, coal, alternative energy, mining resources, water resources and environmental legislation. The course is an elective science core, therefore students have self-selected to participate in an environmentally based geology course.

The population sample consisted of 58 students, 27 males and 29 females. Not every participant contributed to every aspect of the study. Sample numbers for each assessment are included in the results section of this study. Class distribution consisted of 43% freshman, 38% sophomore, 14% juniors and 5% seniors. 48% of the students had taken a geoscience course prior to GEOL 102 and 44% of those students took a geoscience course at MSU. Only 25% of the population had participated in a previous field trip and 4% had participated in a virtual field trip. Nearly all (95%) of the population own a personal computer (Appendix C).

Pilot Study

Prior to the comparison study, a pilot study was conducted to determine the clarity, accessibility and usability of Water Wars virtual field trip. Five students from an introductory physical geology course completed a walk-through of the Water Wars virtual field trip. Following the walk-through the students participated in a focus-group interview where they discussed usability aspects related to Water Wars virtual field trip. The complete pilot study is discussed in the following chapter.

Experimental Design

The experimental design of this study follows a modified Campbell and Stanley (1963) pre-test/post-test control group design (Figure 4). All 58 students enrolled in Environmental Geology are required to participate in lecture and laboratory components associated with the course. The class was divided into two groups; Group A (virtual field trip as pre-activity) and Group B (virtual field trip as post-activity).

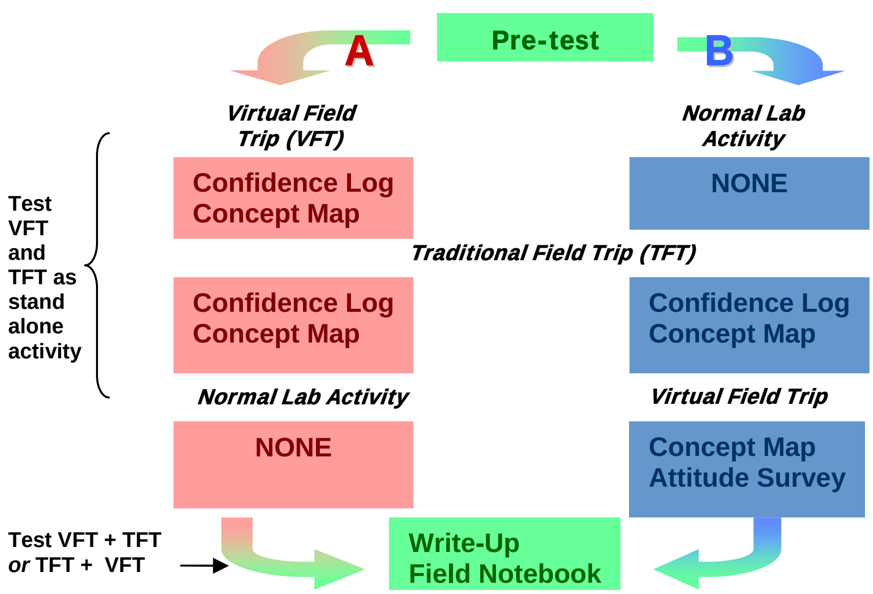


Figure 4. Schematic diagram of Pre-test/Post-test experimental design.

The study period was divided into three phases spanning three learning sessions. Each session consists of two 75-minute lectures and one two-hour laboratory session. A seventy-minute groundwater lecture took place prior to the first learning session. Groups A and B participated in learning session one, a pre-field trip laboratory covering basic groundwater hydrology. In session two, group A participated in the virtual field trip (during their allocated two hour laboratory session), while group B completed a class debate (on the subject of water rights), a normal laboratory activity for GEO 102. Students involved in the virtual field trip were divided into groups of two individuals. Each pair had a computer linked to the internet where they found the virtual field trip linked to the class webpage. Students were asked to complete a 'field notebook,' answer questions, make sketches and record observations at each stop in the virtual field trip. The students were given little instruction with respect to their field notebooks, however the virtual field trips had several clickable questions (Figure 5) that discussed 'how to sketch' and other relevant instructions. The laboratory instructor/field trip designer was present in the laboratory during the virtual field trip to answer questions and clarify directions. While she did interact with students during the virtual field trip, the virtual field trip contained all the necessary dialog an instructor would normally present in a traditional environment.

The weekend following session two, both groups participated in the traditional field trip. Group A attended the traditional field trip on Saturday while a combination of group A and B students attended the traditional trip on Sunday. Group A students attending the virtual field trip on Sunday were asked to ride in one 15 passenger van and direct their questions to only one previously identified field instructor. These precautions were taken to eliminate cross contamination of ideas between groups A and B. The traditional field trips had three instructors available to answer questions during the trip. Students were asked to keep a field notebook that included sketches, notes and data collected during the traditional field trip. The same laboratory instructor present during the virtual field trip conducted the traditional field trip. She provided students with a brief (2 + minutes) explanation of what they were to achieve at each stop and directed students to their road logs which asked the same questions students addressed during the virtual trip. Students were given little instruction regarding completion of their field notebooks. They were asked to include stop number, time and date for every stop and were aware that their field notebooks were primarily for their own use.

During the final session group B participated in the virtual field trip while group A completed the normal laboratory assignment, the water policy debate. Group B was treated in the same fashion as group A during their virtual field trip experience. The researcher/instructor recorded notes and observations during all sessions of the study.

This experimental design allows for assessment of the student performance having only participated in the virtual field trip, student performance having only participated in the traditional field trip and student performance once they have participated in both trips.

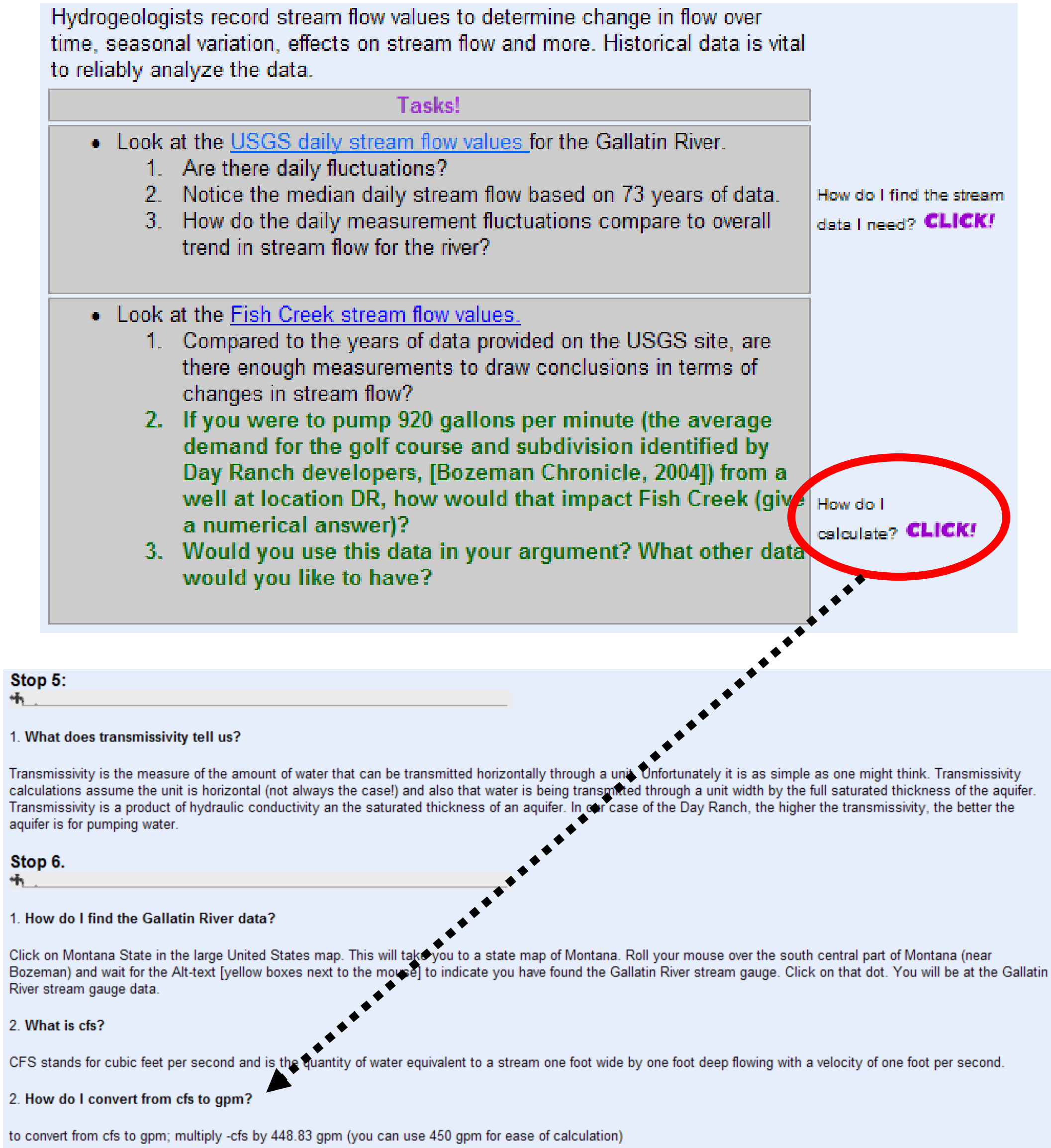


Figure 5- Example of clickable questions. Students click on the question and link to a page responding to each question.

Assessment

Assessment is data collection with the purpose of answering questions about student's understanding, attitudes, skills and instructional design and implementation (Ebert-May, 2004). In this study assessment was conducted in four phases to answer questions and measure knowledge gained; analytical, research and communication skills developed from each experience; confidence and student attitudes toward each experience. Data collection approach was both direct (objective tests, assignments) and indirect (survey) (Ebert-May, 2004). Ultimately, assessment of each field trip helps determine the best use of virtual field trips in Earth Science classrooms.

Pre-test assessment.

A student background questionnaire and content quiz was administered, prior to session one and the water lecture, to determine some general student characteristics (age, gender, major area of study), previous field trip experiences and prior knowledge of common geohydrologic concepts and water rights issues (Appendix B). The pre-test was divided into three sections; (1) demographics, (2) drawing of a groundwater system and (3) six multiple choice questions. While research suggests multiple choice questions hold a diminished potential for assessment of learning (Ebert-May, 2004), the pre-test was designed to determine students' previous content knowledge rather than learning during the exercise.

Virtual field trip assessment.

Following the virtual field trip, students in Group A were asked to complete a confidence log (Thornbury, 2004) and concept map (Zeilik; FLAG 2003) to determine student confidence in completion of the lesson goals and their ability to recall and connect concepts discussed (Appendix A). Student had completed three concept maps prior to the virtual field trip assessment, therefore they had a clear understanding of concept maps and how to create them. Students completed the confidence log and concept map prior to leaving laboratory, therefore participation and completion was guaranteed. The confidence log and concept map were cross-referenced to limit the influence of mood and other factors on level of confidence (Kuvaas and Kaufman, 2004).

Traditional Field trip assessment.

Following the traditional field trip, all students (groups A and B) completed a second confidence log and concept map. At this point in the study, only group A will have completed the virtual field trip, therefore responses from group B reflect the outlook from participating *only* in the traditional field trip. Responses from group A reflect understanding following both the virtual and traditional field trips.

Post-test assessment.

After completion of session three, all students completed a final assessment. Students complete a field trip report graded with a specific scoring rubric (Appendix C) to determine learning outcomes from the virtual and real field trips. This phase of assessment is considered the 'performance assessment' (Slater; FLAG, 2003). Performance assessments help determine if students learn best when the virtual field trip is used as a pre- or post-activity. Field trip reports included a description of the geology of the area, the connection between groundwater and rock units, and a well supported argument for or against the development of the Day Ranch (Appendix A). Students also completed a concept map illustrating how well they grasp the big picture. Concept maps will show how well students recall and understand terminology and link those terms together into a complex understanding of the issue. Students were also asked to hand in 'field notebooks' from both the traditional and virtual field trips. Notebooks were evaluated using specific scoring rubric (Appendix B) to determine skills learned in both settings. As a final attitude assessment, students were asked to complete a short attitude survey reflecting on their reaction to both the virtual and real field trips (Appendix B).

CHAPTER THREE

PILOT STUDY

Prior to conducting the actual comparison and evaluation the Water Wars virtual and traditional field trip, a pilot study was conducted to test the clarity of the virtual field trip and its associated assignment, identify the aspects (question format, image layout, etc.) of the virtual field trip that are particularly effective, and to revise the virtual field trip such that it is a positive learning experience. The goal of this pilot study was to determine how students receive the virtual field trip and identify any changes needed prior to implementing the main study.

Methods

The study sample consisted of five Earth Science 111 (Physical Geology) student volunteers asked to go on the Water Wars virtual field trip and participate in a focus group interview session immediately following the virtual field trip. Water Wars is the virtual component of the field trip experience described in the previous chapters. Participants ranged in age from 20 to 38, freshman to senior class standing. They had diverse major areas of study; hydrogeology, business, secondary education, computer engineering and snow science and all participants had never participated in a virtual field trip. Pizza dinner was offered to students as compensation for the time spent taking part in the virtual field trip and interviews. The focus group interview was held in an open classroom in-the-round. Students spent 2 hours and 15 minutes discussing the virtual field trip with the designer/researcher. A computer was available to point out particular difficulties such as broken links and spelling errors. The following week, students participated in individual interviews. Individual interviews were held in a closed classroom and lasted between 15 and 45 minutes.

During the virtual field trip, the researcher recorded observational field notes, noting such factors as body language, verbal frustration, enjoyment and difficulty navigating. The researcher did not interact with the participants during the virtual field trip experience; she just asked that participants keep notes and stated she would answer questions during the focus group interview. Focus group interview consisted of questions concentrating on the participants' experience with the Water Wars virtual field trip (Table 2).

Table 2- Sample Pilot Study Interview Questions

Focus Group Questions:

1. What was your favorite part of the virtual field trip?
2. What was your least favorite part of the virtual field trip?
3. In terms of navigability, how would you describe this virtual field trip?
4. If you could pick three things to change, what would they be?
5. Is there anything you would like to know more about?
6. Do you feel the goals and outcomes of the field trip were clearly stated?
7. What did you learn from the trip?
8. Did you gain an understanding of how geology is related to public policy?
9. Do you think you have gained a greater understanding of the ground water controversies in Gallatin Valley?
10. Is there anything else you would like to share?

Individual Questions:

1. How would you describe yourself as a learner?
2. How do you think the virtual field trip catered to your learning style?
3. Did you feel motivated by the virtual field trip question?
4. Did you find yourself wanting to know more about subject?
5. Is there anything you felt was particularly frustrating?
6. Particularly enjoyable?
7. How would you improve the virtual field trip?
8. Is there anything else you would like to share?

Participants not only responded to the researcher's questions but also interacted with other members of the focus group, answering questions and discussing situations with each other. Conversation in the focus group concentrated on accessibility and clarity issues as well as the participants' attitude toward this virtual field trip and virtual field trips in general. The individual interviews allowed the researcher to focus on learning style and individual frustrations and enjoyment (Table 2). Participants identified their learning style using a learning style chart and discussed how it affected their virtual field trip experience. Conversation also focused on individual attitudes and experiences with the Water Wars virtual field trip. Although interviews were conducted from a general question rubric, the researcher was flexible and asked questions that appeared relevant to the direction of conversation.

Data analysis began after completion of the focus group interview and all individual interviews. Transcriptions, notes taken by the researcher during the virtual field trip and member check questions were examined for themes, trends, overall attitudes and negative cases. Evaluation of the data revealed themes among student responses. Transcription pages were color coded and information from field notes and member check questions were used to annotate the color-coded transcription pages. Results from this study were drawn from questions regarding the participants experience while taking the virtual field trip, their attitude toward virtual field trips in general and how they see virtual field trips fitting into geoscience curriculum (Table 2).

Results and Discussion

The success of a virtual field trip depends on several factors, one of which the researcher identifies as the "learning environment." For the purpose of this study, the learning environment is characterized by accessibility, clarity, flow and the motivating factors built into the virtual field trip. Because the researcher was interested in improving the quality of this particular field trip, she focused on two questions related to the learning environment, (1) were there situations where the accessibility, clarity and flow hindered learning and (2) was the field trip introduced in such a way that students were motivated to delve deeper into the subject?

Accessibility, Clarity and Flow.

In discussing question one, several themes emerged with respect to accessibility, clarity and flow and the learning environment. Participants identified the lack of necessary information and difficulty locating oneself on given maps as the primary sources for confusion in the Water Wars learning environment.

Necessary information. Participants often became confused when the designer did not include enough necessary information to answer the questions posed. It was clear that the designer, while including what she felt was a necessary amount of descriptive information, needed to include far more information to help students fully understand the nature and the science behind the problem. Often the technical information she believed to be sufficient in explaining a topic was more confusing to the participants than helpful.

> *Ok, right here…"now that you have an understanding of how alluvial aquifers are formed"…where does it say that? Because it is being deposited by the river and we are trying to see if it actively depositing…?* - designer
> *If you clicked in you got an explanation of that didn't you?*
> *Nope* - designer
> *Wasn't there another…*
> *It says "by definition an alluvial aquifer is deposited by rivers"…ok so what is it?*
> *Great but what is it?*
> *What is an alluvial aquifer? (Laughter)*
> *Yea, I clicked on that [definition] it is still…*

> *Alluvium is there –designer*
> *Ok, so go back to alluvium, "eroded, transported"…OK, so that doesn't; tell you more.*
> *But even if you put it in a sentence, so people would know that it is transported sediments…"*

Clearly, participants are confused by technical language and need non-technical, clear definitions to understand what is being presented. Participants suggested the designer "assume that [her] students know nothing" and provide, not only more information, but clear and simple information on *every* topic that students are asked to consider. Technical terminology is necessary, but it is also essential to explain that terminology in layman's terms in order for students to fully understand the concept. Stop one, a location where students observed an active river setting, and stop two, a Tertiary alluvium deposit with sands and gravels, dealt with the idea of alluvial aquifers and uniformitarianism (the present is the key to the past). Nearly all the participants had difficulty making the transition between stop one and stop two and most did not understand the purpose of stop one in relation to stop two. This difficulty resulted from lack of definition of terminology, the designer assumed her participants had a stronger geologic vocabulary.

> *I guess the only problem I did have was, what we were talking about, with stops one and two, there wasn't enough definition for me, it wasn't really clear on what I was supposed to be learning and what I was supposed to be getting out, it wasn't all defined.*

Although there is an extensive glossary, it became apparent that definitions of terms and explanations of geologic processes are necessary and seem to be more successful when embedded in the virtual field trip text. The participants wanted the necessary information "in a sentence" and felt as "little taking you away from the page as possible" was the preferred method of delivery.

Participants also suggested that there was a "fine line between having enough information to make an educated decision, and having [enough to] not get lost." There were situations where the designer gave the students "too much information, too much to take in" and it caused difficulty discerning necessary information from superfluous information included to satisfy curiosity.

> *One thing I noticed was with the links you had in there that are really pertinent to you know, you go to this, it is part of the webpage and it is an important resource or whatever and then there are others that are more of for future references type thing, you should maybe differentiate somehow between the two, I am not sure, it would be helpful as well.*

Results indicate that there is in fact a fine line between too much information and too little information. Two participants felt overwhelmed by information provided to satisfy curiosity, however, another indicated that "more information needs to be in there."

> *It might suck to have to read more, but I…like you had it laid out so well at the end where you said, like, these are the arguments and here is the rebuttal, like, you need to lay the rest out that way.*

While some participants felt there was too much superfluous information and the designer "might want to just do away with them" one participant felt there "needs to be more information" not only to satisfy curiosity but also to produce a quality report in the end. It is important for any information that students feel is necessary to remain in the virtual field trip. While the superfluous information may be slightly confusing to some students, it is considered necessary to others, therefore valuable information for the virtual field trip.

The learning environment must contain information necessary for students to answer all questions posed. The designer should assume that her students know less than expected so as to provide adequate information for ALL students participating in the virtual field trip. It may also be beneficial to make a distinction between information students *need* to know and information that is included for the purpose of enrichment.

<u>Location.</u> The digital learning environment caused some significant difficulties when trying to articulate location. Maps are difficult to present clearly, it is difficult to place oneself in three dimensions through a two dimensional medium and prior experience in the field has an extreme effect on locating oneself in the field area.

The researcher found that prior experience in the specific field area helped participants locate themselves more easily. Those who were new to the area or had not been out on the River Road had the most difficulty with locating themselves digitally.

> From the area:
> *I have been out there, driving around…knowing that area already really helped, made it a better experience.*
> *So you didn't have as much of the* where are we *problems* - researcher
> *Yea I had almost none.*
> Not from the area:
> *The first initial (where the heck am I) yea…that was the hardest thing for me, maybe because I don't know the area as well as some of the other people.*

Although previous experience in the field area did help with locating oneself, one participant had been through the area "MANY times…[and] still didn't remember all the features exactly." He felt since he had never been called upon to examine the geology of the area, he never really paid attention to the geology of the area. The participant who had the least difficulty with location had been out River Road numerous times and spent time at the Gallatin River and exploring the area. Although it seemed that previous experience did have some effect on participants' ability to locate oneself digitally, the amount and type of experience also played a role in how well one could locate oneself digitally. No matter the experience all participants did find it *more* difficult to locate themselves in the virtual field trip than they had experienced on previous traditional field trips.

Maps are difficult to display digitally and at times even more difficult to understand in a virtual setting. The topographic maps were downloaded from Topofinder™, a digital archive of Department of Interior topographic maps broken up into 5 x 7 inch segments (http://nris.state.mt.us/topofinder2/default.asp). Because of the nature of the downloading program, the topographic maps provided in each section to contain location information such as "you are here, you are here, you are here, but [they] have no relevance to where the Day Ranch is" in relation to Bozeman, Montana and the University. Participants found this particularly confusing. They could not tell where they were, "sure [they] know [they] are here, but where is *here*." It was clear that one of the greatest challenges of designing this virtual field trip was trying format the maps to provide the information needed for the participants to successfully locate themselves. Because the participants were not in a three dimensional space, driving from place to place, they had great difficulty determining where they were.

> *I think that sometimes in a virtual field trip I felt, like, lost, like where am I, where if you are actually THERE, you have some…distances you know, you are going or directions… …but [in a virtual trip] you don't get to turn to the south and SEE, oh that's where we are, this is where we are and that's how it fits.*

Participants suggested the designer combat this problem by "walk[ing them] along where [they] are going" and "put[ing] a scale on the topo map so [they] can see how far [they] have gone. The designer has done just that but still feels that interpreting the maps available will continue to inhibit learning on the virtual field trip.

The virtual field trip also failed to explain a fundamental point with respect to the location of each stop. One participant had particular difficulty determining his location in relation to the Day Ranch. This was largely a function of the maps provided and lack of explanation of where the participants were going and where they would end up.

> *So all the stops are not even on…so the other stops you have made are just so you understand the geology?*
> *We actually never go on the ranch property* -designer
> *So why would the geology of places [that] are nowhere near the Ranch would have anything to do with the Ranch itself?*
> *They are the same* -designer
> *Why wouldn't you use stops, examples, within that area? To come to the same conclusions?*
> *So you don't get sued (Laughter)*
> *We can't get on the property…that is the main point, and also you can't see the gneiss outcrop on the Day Ranch* -designer
> *So maybe just let that be known, pretend I am dumb, and say these formations here will similarly be found on the Ranch, it is kind of inferred but…*

The participants suggested adding a "little blurb at the beginning *we are not going to go into the Day Ranch but the stops we are going to make exemplify the Day Ranch geology* *and this is why we are doing this.* That would have helped me at the beginning." This material again was added and seemed to make the sequence of stops more logical and understandable.

Location is one of the most difficult subjects to simulate digitally. There are inherent difficulties related to map reading and use. Students have difficulties interpreting maps and extracting three-dimensional information from two-dimensional objects. Digitized maps are challenging to work with and until technology advances, will most likely remain an inhibitor to learning with a digital medium. In order to ensure that all students have the chance to locate themselves on a virtual field trip digital maps, must be clear and readable and travel and distances must be plainly explained. It is also helpful if a student has previous experience in a field area, suggesting that a virtual field trip may work better as a supplemental task to a traditional field trip, rather than a stand alone exercise.

Motivation.

Student motivation is essential to a successful learning environment (Edelson, 2001). Students must be compelled to learn by the subject, activities and assignment. The Water Wars learning environment was particularly motivating to the five participants in this study. They enjoyed "the layout, it has all the right ideas." and they felt the "outline of it was set up really nicely." It brought up "whole new things that [students] can look into and probably won't hurt learning more about." "It does a good job about that, motivation!" Participants enjoyed "knowing [about] controversies and stuff, like everything, one side and the other." They really liked how the designer used a case study approach to "explain the controversy" and used the argument as a tool to facilitate understand of the geologic history and setting of the Gallatin Valley.

Prior interest in the subject also plays a significant roll in student motivation. Four out of five participants had some experience with ground water controversies that made them interested in participating in the study. One participant had "been through water rights, you know, owning land, [he] still found that interesting." Another was a hydrogeology major interested in learning how water effects the public. A brief conversation during the focus group interview revealed that the participants were genuinely interested in the topic of water rights and were externally motivated to learn more about Water Wars in Gallatin Valley rather than internally motivated by the virtual field trip text.

Attitude.

An effective learning environment is not the only factor that ensures the success of a virtual field trip. Students must enjoy the process of going into the "field" virtually and sense they have learned something from such an experience. Their attitude toward the virtual field trip experience is fundamental to the success of any virtual field trip. The researcher was interested in two questions with respect to students' attitude toward virtual field trips; (1) what are students' attitudes toward the Water Wars virtual field trip *and* virtual field trips in general and (2) how do they see virtual field trips fitting into the Earth Science curriculum?

Water Wars Virtual Field Trip.

Participants enjoyed partaking in the Water Wars virtual field trip. They felt they learned something even when only required to walk-through and critique. The virtual field trip "gave a lot of pertinent information…that…is good for everyone to know." They really enjoyed the exposure to a new issue and some even hoped to learn more about the issue than they did in the hour and a half exposure to the topic.

> *For me it was a great appetizer, it made me want to delve into the stuff a lot further.*
> *I actually want to know more about this now, it just brings up more topics than were initially…it brings up whole new things you can look into and probably won't hurt learning about.*
> *Yea, I am gonna, like now when I drive that [the road] I am actually going to look around…every time I go down [it] I'm gonna be like Oh alright, I see how the aquifer is doing and stuff.*

Two participants particularly enjoyed the pictures and the visual nature of the virtual field trip. Although, they felt there could have been more photos and possibly streaming video or panoramic photos to "keep you entertained" and keep it from getting "really boring."

> *My favorite part was the pictures, they were linked to other pictures within a picture.*
> *I thought the pictures too [were good]…you could see the far away view and you see a couple links in there… [you could] click in and zoom in and back out and go to another spot and compare them.*

Three participants indicated that the layout and presentation of the information were particularly enjoyable. They "really liked how it brought a good introduction and wrapped it up well." They "thought it explained the controversy well" and "how [the designer] set it up where [she] defined how it holds water and how [she] leads into the controversy."

> *I enjoyed the whole thing really…I was interested in the way it tied together, you know, this is more a sponge, this is more of a stop, a dam, where is it going to go, how is it going to work. So that was my favorite part, you know, just thinking about it that way.*

Overall, the least enjoyable part of the Water Wars virtual field trip was a built-in bias. Participants got the "sense that [the designer was] pushing that the Ranch is not a good idea." The designer presented the topic in favor of the Gallatin County Commissioners since the field trip was designed for an environmental geology course. The participants felt that bias was unnecessary and including it was doing a disservice to the students' learning process. They felt the students should be left to decide on their own which side to support.

> *I just think that if you are doing a study, especially if you are asking questions, what do you think, you know, what do you think, how can you be bias one way when you are asking questions like that?*
> *I actually thought the arguments on the Ranch side were actually better. I don't know if that comes from your bias in that you didn't think you needed to put as much on your side to prove your point because assuming everybody already felt like that, you know what I mean?*

One participant felt, given the assignment, (role-play as an expert geologist, develop a well-supported argument regarding development permits) the bias should remain:

> Participant 1: *Depending on how you want it to sound, you know keep the bias the same… (giggle) or…lessen it so the people on their own can make their own decision instead of being prodded in one direction.*
> Participant 2: *I wouldn't do that myself because you are trying to support the lawyers' side, I mean the County Commissioners side of view.*
> Participant 1: *That is our job, not hers. She is giving it to us.*
> Participant 2: *We are being biased, we are ASKED to be biased.*
> Participant 1: *I would rather be left to… once you are given all the information, I think it should be ultimately up to the individual who is going to make the decision which side…*
> Participant 3: *I think though too, if it is an environmental geology class, don't you want to get across the point that there are environmental factors to geology, you know like, maybe you should argue the point of…be a little bit bias because it is*

After much discussion, it became clear that the bias should ONLY remain if the assignment requires students to be biased. Participant 2 was only "comfortable with the bias because it was [his] job." If that job changes, the designer "is going to have to change the whole tone" of the virtual field trip. Without the required bias, participants felt "definitely throughout the whole thing [the designer] will have to look through some bias things" and change them to a more neutral position.

One participant was slightly disappointed with what the researcher suggested was a *virtual* field trip. He felt that calling the activity "a virtual field trip… might be a little over the top." He thought it was "basically an elaborated lab." He did enjoy participating in the study but felt a three dimensional experience would have been more appropriately dubbed a virtual field trip rather than the activity the designer referred to as a virtual field trip.

Overall, the participants enjoyed the Water Wars virtual field trip. They felt there were a few little things that needed “tweaking” but the content and presentation were enjoyable and useful. They all agreed that they learned something and indicated that they would enjoy completing the activity as part of a course.

Conclusions

When investigating student attitudes toward virtual field trips, two main themes emerged as controlling factors to the success of the Water Wars virtual field trip. A positive learning environment is necessary to reduce inhibitors to learning such as motivational issues, accessibility, clarity and exercise flow problems. In the Water Wars field trip, inhibitors such as the lack of necessary information and difficulties locating oneself were distracting to students. The unclear maps and lack of information resulted in students getting lost and frustrated with Water Wars. Students identified that such inhibitors must be reduced to nearly zero to ensure the success of such an activity.

A positive learning environment must also motivate students to learn about the subject posed. The layout and introduction in any activity intrinsically motivates students, but it also became apparent that students’ previous interest in the subject can also serve to motivate. While students felt motivated by the actual Water Wars activity, the case-study approach and focus on a local problem was particularly motivating. It was also apparent that prior experience has a strong effect on student motivation. Nearly all the students participating in this study had some previous experience and interest in water issues. Their prior experience created natural motivation to participate in the study and learn about water issues in the Gallatin Valley.

Several changes were made to the virtual field trip following this pilot study. Maps were altered and annotated to make them easier to read and more user friendly. Wording in the introduction was clarified such that the purpose of the field trip was very clear, the argument was clearly stated students were aware of where they were going to go on the trip. Finally, an attempt was made to eliminate any bias. More data was gathered describing the developers' point of view and wording was changed to convey a more neutral point of view.

CHAPTER FOUR

RESULTS

This section discusses the outcomes of the study: whether virtual field trips successfully address learning goals expected from traditional field trips, and the order in which virtual field trips should be used; whether they are more effective as a pre-activity or post-activity relative to a traditional field trip.

Learning Goals: Hypothesis 1 (Table 1)

The Water Wars field trip addressed many objectives associated with traditional field trips. Students were to develop observation, question asking and hypothesis writing skills, gain the ability to critically evaluate the validity of data and evidence used in environmental disputes, learn how to use data properly and critically, and gain an appreciation for the complexity of environmental and geologic issues. The virtual and traditional field trips addressed the same objectives and students' notebooks, concept maps, confidence logs and reports were evaluated to determine if all learning goals were addressed on the virtual field trip.

Field notebooks, both virtual and traditional, were assessed using a scoring rubric designed to evaluate the ability of each field trip to address learning goals associated with traditional field experiences. The rubric evaluates five aspects of the field notebooks; questions posed at stop 5, the stop where the Day Ranch controversy was first addressed formally; hypotheses created to explain an unconformity in the valley; quality of sketches; note detail and completeness of notebook. Each aspect was given a score on a 10 point scale, 10 being exemplary and 0 indicating the student did not address that particular aspect in their notebook (Appendix B). Criteria for numerical scores varied depending on the aspect. In general, a score of 10 would require the student to convey their full understanding of topics discussed in a neat and legible manner. Notebooks would include all the required material as well as additional information related to the topics and stops. A score of 4 or less indicates students did not fully address the aspect being evaluated or provided information that was entirely incorrect. Low scoring notebooks showed little to no attention to detail and lack of effort (Appendix B). Fifty-one participants handed in both field notebooks, 1 virtual notebook and 3 traditional notebooks were typed. Seven participants did not submit both field notebooks were eliminated from this part of the study. Total virtual and traditional notebook scores were plotted on histograms to test for a unimodal, normal distribution of scores (Figure 6). Total scores were computed by adding all rubric categories, total points possible was 50. Median traditional scores were similar for groups A and B, 32 out of 50 possible. However, mean scores were slightly higher in group B (mean, B: 33/50; mean, A:29/50). Group B scored slightly higher (median, 33/50; mean 33/50) than group A on virtual notebooks (median, 31/50; mean 29/50). All populations display a unimodal, roughly normal distribution and populations were analyzed accordingly.

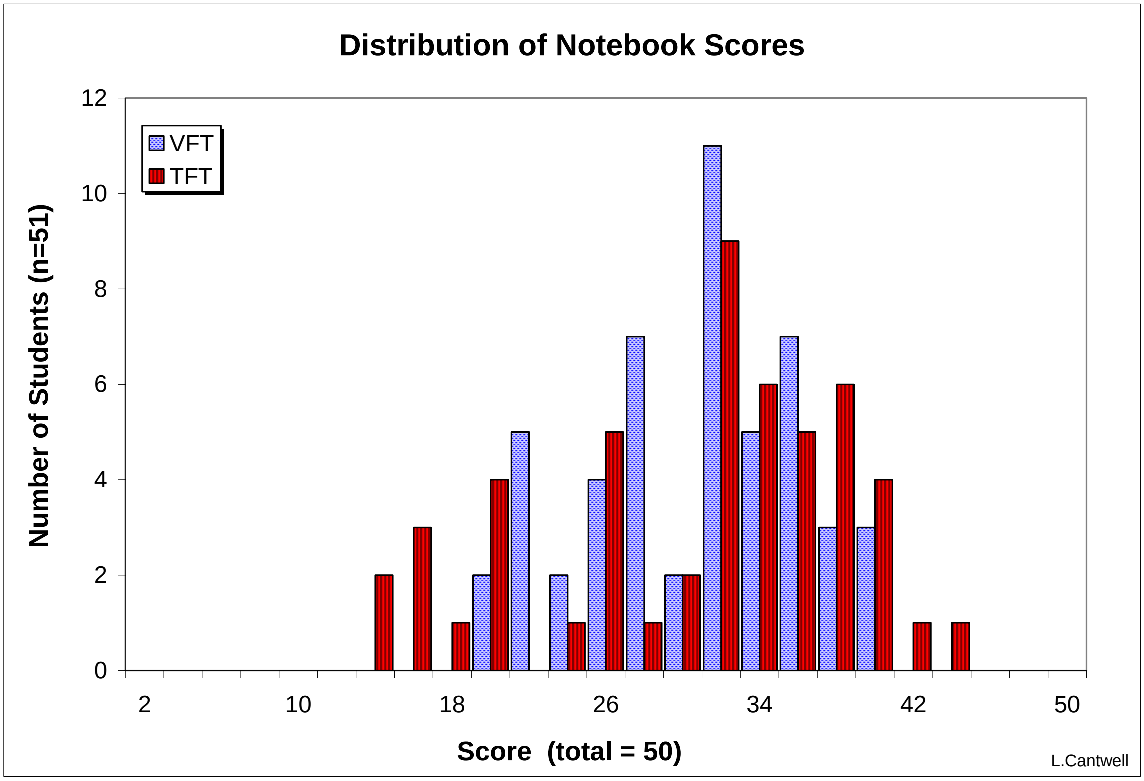


Figure 6 - Distribution of virtual and traditional notebook scores. Rubrics consisted of a total of 5 aspects, each scored on a ten point scale. Distributions are plotted as total scores (all 5 aspects added together) out of 50 points. All scores are unimodal and normally distributed; therefore assessment results can be treated as statistically normal.

Observation Skills: Hypothesis 2a (Table 1).

Sketches and note detail were used to evaluate how well each component accomplished teaching observation skills. Participants made ‘field observations’ from photographs provided in the virtual field trip. Many photographs were clickable such that users could zoom in and zoom out as well as see objects from different perspectives (Figure 3). Virtual field trip participants scored a mean of 5.7 (out of 10) on their virtual field notebook sketches (“sketches”-Table 3, Figure 7), indicating sketches were somewhat neat, included limited information in sketches, some scale information missing, 2 or more errors.

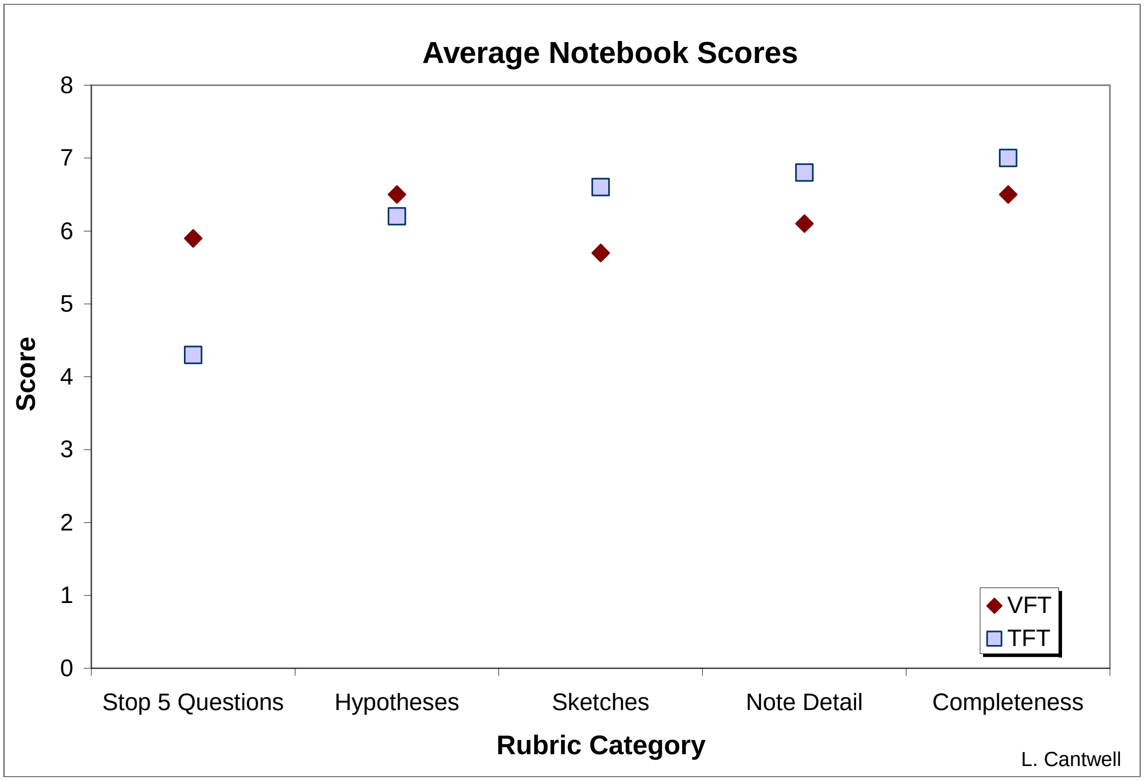


Figure 7. Mean virtual and traditional notebook scores. Difference in stop 5 and sketches scores are statistically significant (two tailed t-test, p-value= 0.007 and p = 0.006 respectively). Note detail scores are statistically significant (p = 0.012). Hypothesis and completeness scores are not statistically significant (p = 0.577 and 0.164 respectively). Significance determined at the 95% confidence interval (Appendix C)

Sketches in the virtual field notebooks were neat and legible (Figure 8), however participants' perspective was restricted to the photos on the computer screen. Sketches were limited to the detail participants could see on the screen (the outcrop) and most often did not include additional observations about the surroundings. In one instance, when asked to draw an outcrop of Tertiary sediment (finer-grained sediment or sedimentary rock, Upper Tertiary [Vuke et al., 2002]) many drew a graded bed of large cobbles grading up to fine-grained sediment. As a function of photograph position, participants viewed an outcrop with two large cobbles near the base (Figure 9) as graded. One student acknowledged that "the Tertiary sediment was much different than how [she] pictured it." Students were also inclined to draw sketches that resembled an example sketch more than the outcrop itself (Figure 10). Virtual sketches were, for the most part, neat; however, they did not include sophistication and information the researcher considers to be indicative of thoughtful, careful observations.

Table 3- Students notebook scores, assessed for specific information that reflects their ability to address certain learning goals. Each column corresponds to a rubric category that assesses different learning goals (Appendix D). Statistical analyses and full data sheet in Appendix C.

Group	Field Trip	Stop 5	Hypotheses	Sketches	Note Detail	Total
A Mean	*VFT*	*5.6*	*5.6*	*5.6*	*5.8*	*29*
A Median	*VFT*	*6.0*	*8.0*	*6.0*	*6.0*	*31*
St. Dev.	*VFT*	*2.12*	*2.95*	*1.32*	*0.90*	*5*
B Mean	*VFT+TFT*	*6.0*	*8.3*	*5.6*	*6.5*	*33*
B Median	*VFT+TFT*	*6.0*	*8.0*	*5.5*	*6.0*	*33*
St. Dev.	*VFT+TFT*	*2.22*	*0.99*	*0.85*	*1.29*	*5*
Class Mean	***VFT+TFT***	**5.9**	**6.5**	**5.7**	**6.1**	**32.07**
A Mean	*TFT*	*3.9*	*5.8*	*6.3*	*6.5*	*29*
A Median	*TFT*	*4.0*	*8.0*	*6.0*	*6.0*	*32*
STDEV	*TFT*	*3.41*	*3.42*	*1.93*	*1.41*	*9*
B Mean	*TFT+VFT*	*5.1*	*6.7*	*6.9*	*7.2*	*33*
B Median	*TFT+VFT*	*6.0*	*8.0*	*7.0*	*7.0*	*32*
STDEV	*TFT+VFT*	*2.50*	*2.46*	*1.51*	*1.53*	*5.43*
Class Mean	***TFT+VFT***	**4.3**	**6.2**	**6.6**	**6.8**	**32.26**

Sketches from traditional field notebooks were somewhat messier and harder to read, however participants scored (mean 6.6, "sketches"-Table 3, Figure 7) higher on their traditional notebook sketches than their virtual notebook sketches ($p = 0.007$). Traditional sketches often included environmental information, additional labeling, details about the environment and sophistication that was missing from virtual sketches (Figure 8). Many participants identified observation skills as one of the major skills they developed during the traditional field trip. Participants acknowledged “visual understanding,” the ability to “differentiate between soil and rock types,” and “a good grasp of what everything looks likes and where it is,” were primary skills they developed during the traditional field trip.

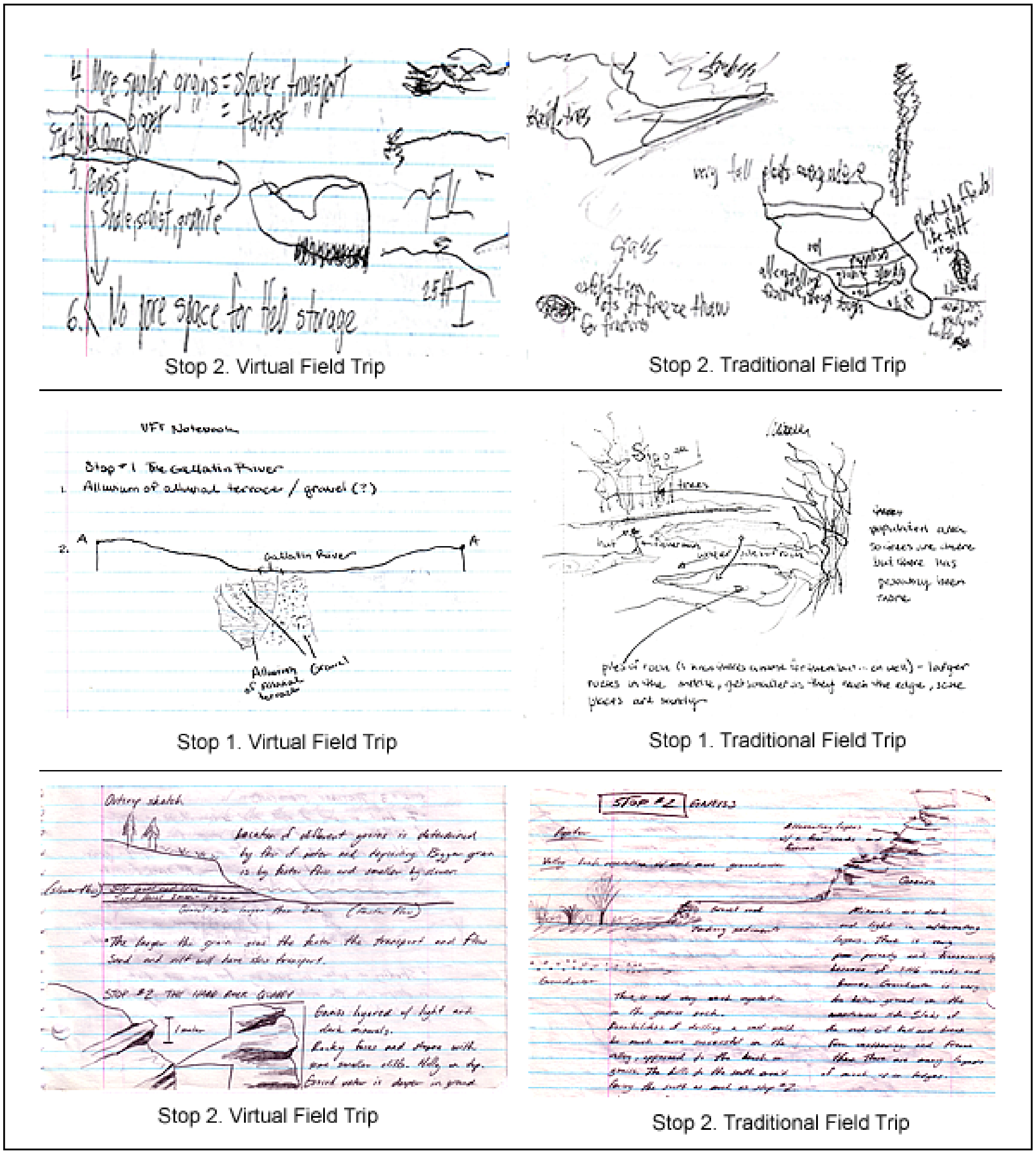


Figure 8 - Example of student notebook sketches. Traditional field trip sketches include more detailed descriptions and accurate depictions of outcrops and stop location.

Another measure of participants' observation skills was note detail, in particular descriptions of landscape features, definitions, ages, dates, terminology and stories

(Rubric in Appendix B) included in notebooks. It was assumed that participants with highly detailed notes were more attentive to their surroundings; however, this may also be a measure of listening skills. Those who listen carefully to the instructor may have added note detail. With that in mind, note detail was still used to evaluate observation skills.

Participants involved in the virtual field trip demonstrated average detail in their notes, mean score 6.1 (somewhat detailed, limited terms, “note detail”-Table 3, Figure 7). Participants answered the questions, however did not elaborate on answers (i.e. add terminology to answers, include ages when describing rock units) and did not include additional relevant information in their notes. Their notes sufficiently addressed the tasks, though did not illustrate convincing observation of the surroundings or attention to details in the ‘virtual field.’

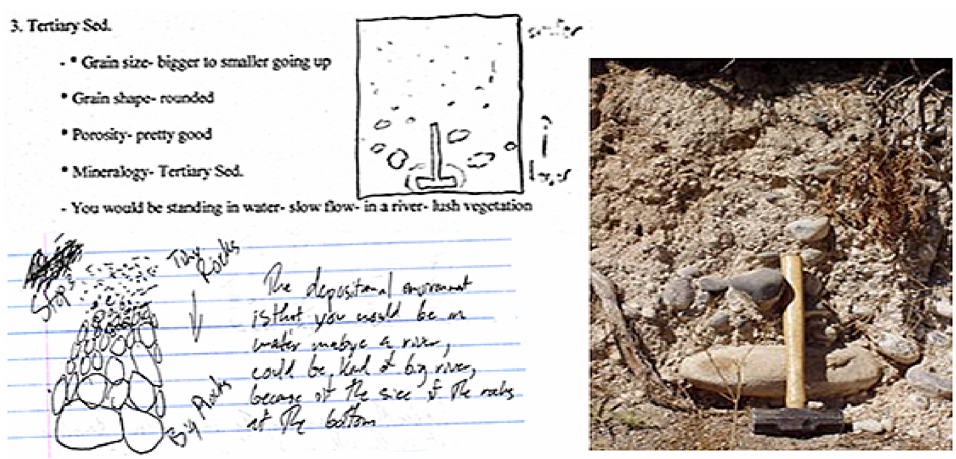


Figure 9 - Example of virtual field trip sketches that depict gradational Tertiary sediment outcrop and photo included in the virtual field trip.

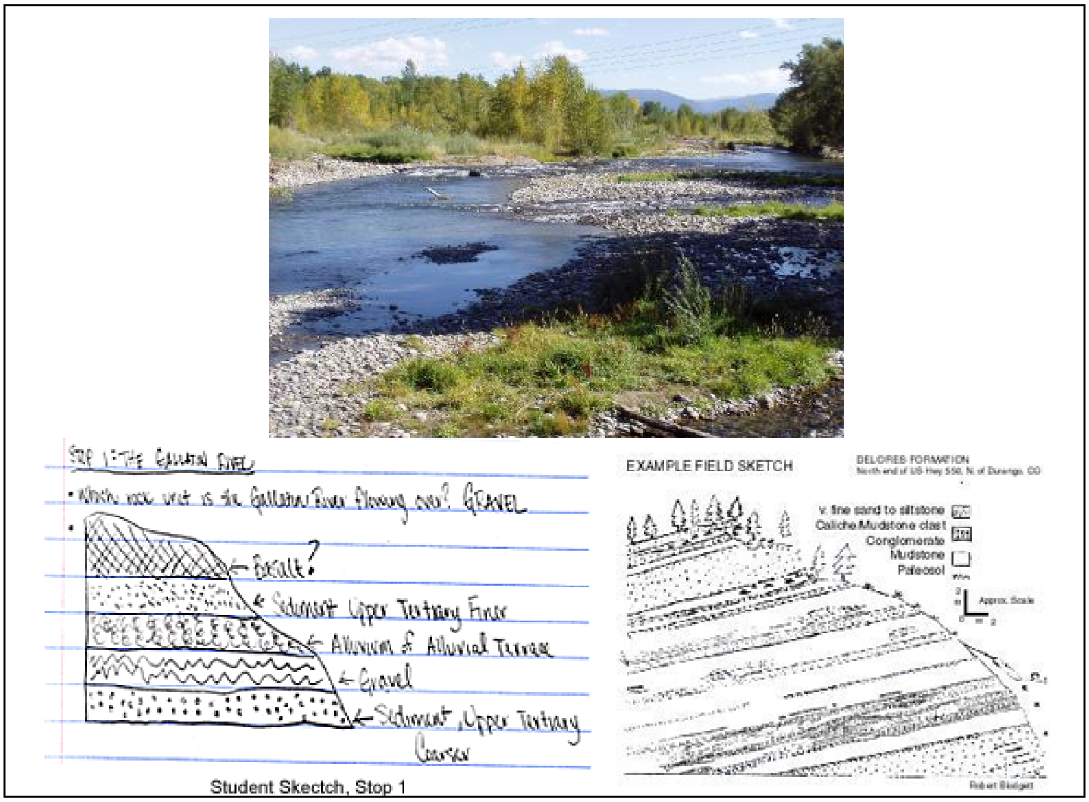


Figure 10 – Example of student sketch (left image). Photo is the image students were asked to sketch and lower right is example given in 'clickable questions' page. Notice student's image resembles example rather than image given.

Traditional field trip notes scored higher (mean 6.8, "note detail"-Table 3, Figure 7). Many notebooks had information recorded during discussions and instruction lectures that preceded or followed the tasks at each stop. Participants were less likely to include specific terminology or definitions in their notes; however, notes did indicate attention to details and surroundings. Participants recorded physiographic, biologic and ecological information as well as geologic and hydrologic information required.

Question and Hypothesis Development: Hypothesis 2b (Table 1).

At Stops 2 and 5 in the virtual and traditional field trip, participants were asked to develop a hypothesis and pose questions, respectively, about phenomena and issues related to the field trip content. Participants were asked to role play as hydrogeologists, evaluate the Day Ranch issue and pose questions they, as hydrogeologists, might be considering while evaluating the area for its development potential and water use possibilities. Participants were also asked to develop a hypothesis regarding the formation of a significant unconformity in the field area.

Questions posed during the virtual field trip yielded average scores (mean 5.9, “stop 5 Questions”-Table 3, Figure 7). Students were able to ask reasonable questions, however, results do not indicate participants were able to develop sophisticated, overarching questions related to the problem. The questions submitted indicate students understand the basic premise of the trip but lack complexity and creativity. Questions written in the traditional trip notebooks were less sophisticated (mean 4.3, “stop 5”-Table 3, Figure 7), however participants engaged in a meaningful conversation regarding the Day Ranch issue while in the field. Many participants did not include any questions (31%) and those who did include questions only wrote minimal and simple questions. Students verbalized insightful and intelligent questions in the field, yet failed to record those questions in their notebooks.

Students also completed confidence logs that addressed their confidence with respect to tasks and problems associated with Water War’s learning goals. Thirty-eight students responded to the virtual field trip confidence log, 15 responded to the traditional field trip confidence log. Confidence log results reflected students' confidence related to asking valuable questions with respect to the problem. Virtual field trip participants felt confident (50%, Figure 11D) in their ability to ask important questions regarding the issue; however few were very confident (7.9%, Appendix C). Following the virtual field trip, 39.5% of the students were somewhat confident in their ability to ask valuable questions and 23.7% felt little confidence. Traditional field trip participants were more confident in their ability to ask questions regarding the issue (Figure 11D); 27% very confident, 57% confident, 27% somewhat confident (Appendix C), than those involved in the virtual field trip.

Participants involved in the traditional field trip developed sufficient (yet not comprehensive) hypotheses for the unconformity in the area (mean 6.2, "hypotheses"-Table 3, Figure 7). Participants' responses lacked detail about formation of the unconformity and some hypotheses did not related to the actual geology in the area. It was apparent participants understood the concept of hypotheses and briefly considered formation of the valley stratigraphy and unconformity. However, hypotheses lacked details which would indicate complex and complete understanding of the geologic history of the area. Participants were asked to write a hypothesis in the van prior to seeing the actual unconformity contact and discussing the formation possibilities. Many recorded hypotheses resembled the wording discussed in the field, therefore it is unclear if participants did write their hypotheses prior to discussing the formation possibilities. It is assumed that results are not skewed by instructor input and discussion. Hypotheses posed during the virtual field trip scored slightly higher (mean 6.5, "hypotheses"-Table 3,

Figure 7). Students were able to relate the hypotheses more specifically to the geology of the valley and pose hypotheses that are geologically possible with respect to Rocky Mountain geology. Virtual field trip participants had well data readily available and most participants were involved with the instructor in a discussion and explanation in order to understand fully the nature of the contact. Hypotheses posed in virtual notebooks closely resembled wording used during discussions.

Evaluate and Use Data: Hypothesis 2c (Table 1).

Participants were required to use and evaluate data during the virtual and traditional field trip experience. Those involved in the traditional field trip measured stream flow from Fish Creek using the Floating Stick Method (MDEQ, 2004). Those participating in the virtual field trip were given data and an explanation of the method used to measure that data. Participants were asked to consider and discuss if they would use data either given or measured during the field trip and if they would like more information to make a logical argument. Eighty-two percent of the participants were comfortable with using the data they were given in the virtual field trip, only 8% would not use any of that data, 10% did not respond.

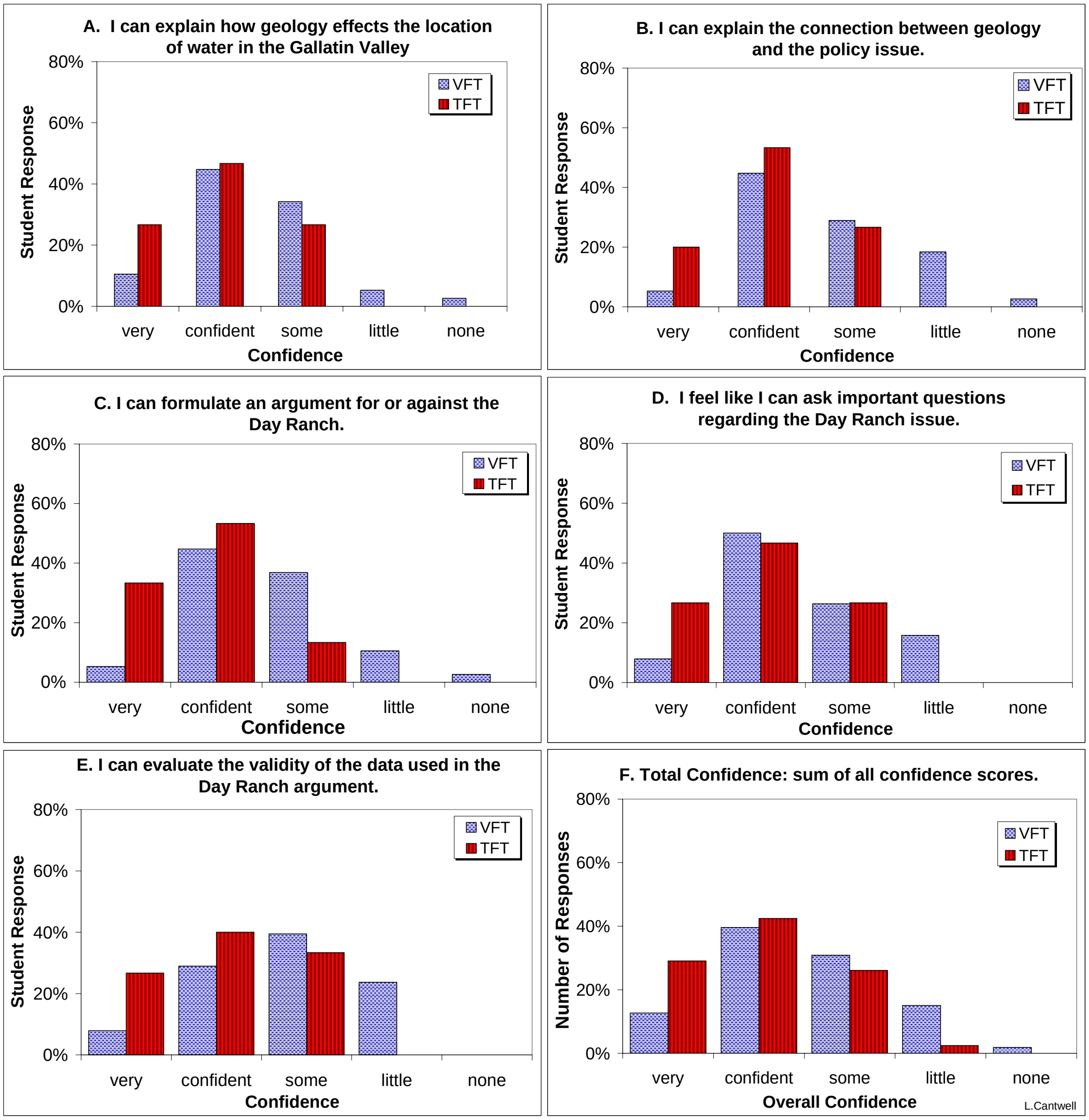


Figure 11 – Confidence log results. Group A: VFT results collected following *only* the virtual field trip, n = 38. Group B: TFT results collected following *only* the traditional field trip, n = 14.

Sixty-three percent of the virtual field trip participants would have liked more data to use in their argument while 29% were not interested or did not indicate they would like more data to be used in their argument, 8% did not respond (Figure 12). Thirty-one percent of the participants involved in the traditional field trip would use the data they measured in the field, 8% would not and 61% did not respond. Twenty-seven percent of the traditional field trip participants would have liked to measure more data, 16% were not interested in or did not indicate they would like more data and 57% did not respond (Figure 12). Since over half of the participants did not respond to the question, it is difficult to use these data points in this study.

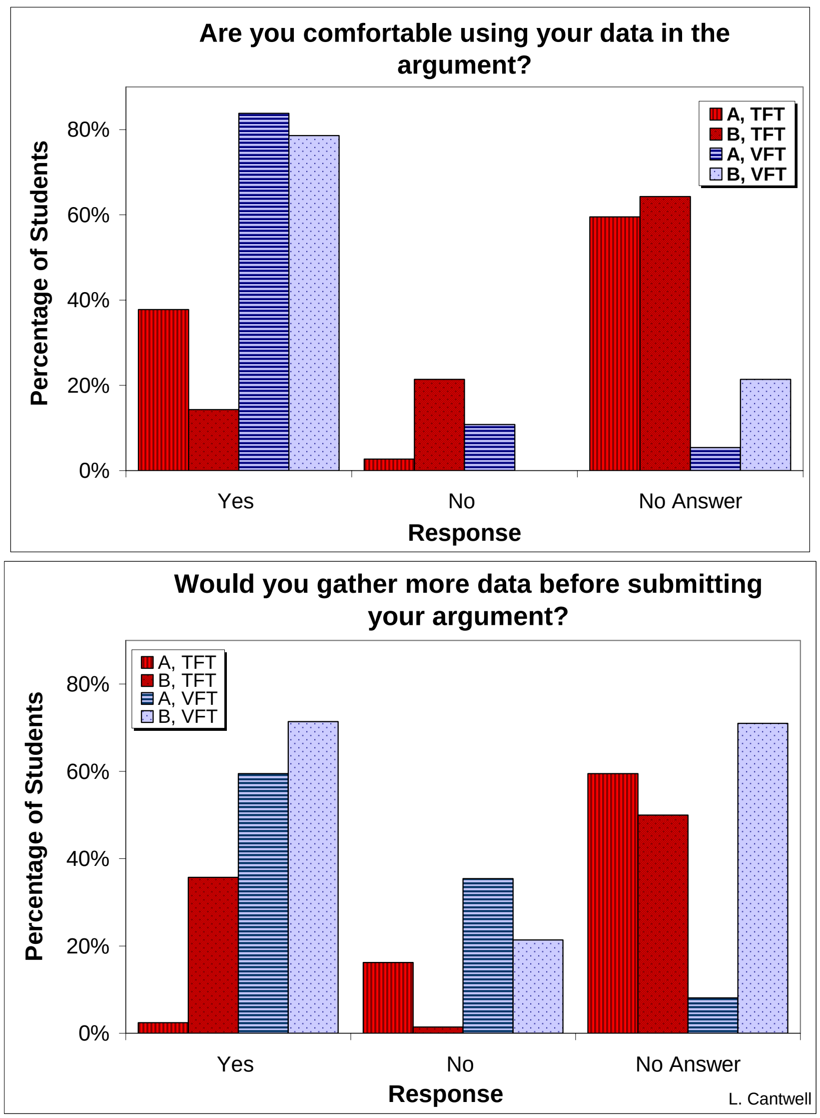


Figure 12. Number of students willing to use data given or recorded during the virtual and traditional field trip and number of students interested in having more data to evaluate the issue (Appendix C).

Those involved in the virtual field trip felt less confident in their ability to evaluate the validity of data used in the Day Ranch argument than participants in the traditional trip (Figure 11). Nearly eight percent of the participants in the virtual field trip were very confident in their data evaluation ability, 28.9% were confident, 39.5% were somewhat confident and 23.7% had little confidence. While, 27% of those who participated in the traditional field trip felt very confident with their data evaluation ability, 40% were confident and 33% were somewhat confident (Figure 11E, Appendix C).

Appreciation for the Complexity of the Issue: Hypothesis 2d (Table 1).

One of the main learning goals of this field trip experience (and the Environmental Geology course for which the trip was designed) was to help students develop an appreciation for the complexity of geologic issues. Field trip reports were a culmination of all the knowledge and content dealt with in the field trip experience. Participants were asked to role-play and develop an argument supporting or opposing the Day Ranch development. Fifty-four participants handed in final reports, 38 from group A and 16 from group B. Reports were graded with a scoring rubric that addressed report content, application of that content, relevance of the content included, insight and thought about the problem and mechanics (Appendix B). Reports were given a score out of a total 40 points. A score of 40 would require a clearly stated and well supported argument that fully addresses the questions and any other relevant questions. Total scores show a slightly skewed right, unimodal distribution (Figure 13).

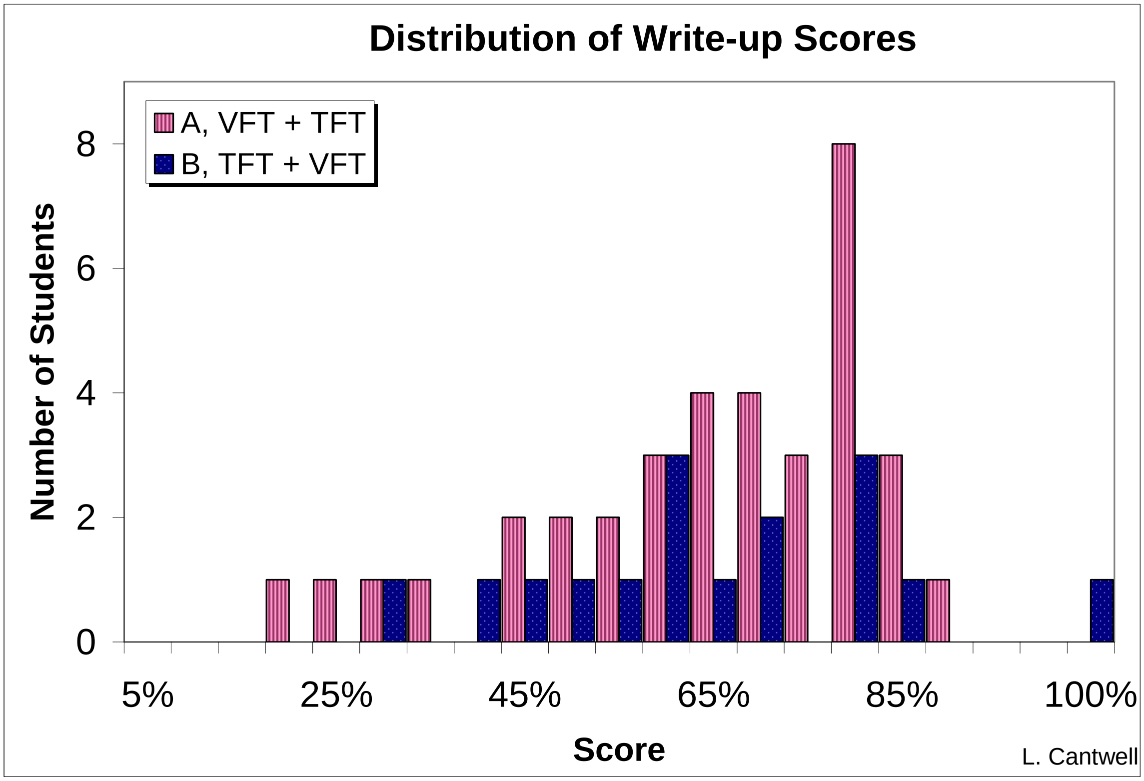


Figure 13- Distribution of class write up scores. Scores are given as a percentage (% = (X/40)*100). Group A mean = 63.5%, Group B mean = 62.8%, difference is not statistically significant at the 95% confidence level (Appendix C).

Scores for the write up were average (63%, Table 4) indicating that participants thought about the problem and included necessary information, however did not fully articulate the complexity involved in the geohydrologic problem.

Table 4- Final report scores and percentages, pre-test scores and percentages.

Group	Final Report	%	Pre Test Multiple Choice	%	Pre Test Drawing	%	Pre Test Average	Change from Pre- to Post-test
A Mean	25.38	63.5%	7.3	72.8%	7.58	33.6%	53.2%	10.3%
A Median	26.50	66.3%	8.0	80.0%	7.00	31.8%	55.9%	10.3%
StDEV	6.97	17.4%	2.5	24.7%	4.75	22.0%	19.3%	
B Mean	25.13	62.8%	7.0	70.3%	7.06	32.1%	51.2%	11.6%
B Median	24.75	61.9%	7.0	70.0%	5.25	23.9%	51.9%	9.9%
StDEV	7.24	18.1%	2.0	20.2%	5.62	25.5%	17.9%	
Class Mean	*25.25*	*63%*	*7.2*	*72%*	*7.32*	*33%*	*52%*	*11%*

Those involved in the virtual field trip were confident in their understanding of the issue (Figure 11). Over five percent involved in the virtual field trip felt very confident in their ability to formulate an argument for or against the Day Ranch development, 44.7% were confident, 36.8% were somewhat confident, 10.5% had little confidence and 2.6% had no confidence whatsoever. When asked how confident they were in explaining the connection between the geology and the Day Ranch issue, 5.3% of those participants involved in the virtual field trip responded ‘very confident’, 44.7% were confident, 28.9% were somewhat confident, 18.4% had little confidence and 2.6% had no confidence whatsoever. When asked if they can explain how geology effects the location of groundwater, 10.5% of those involved in the virtual field trip were very confident, 44.7% were confident, 32.4% were somewhat confident, 5.3% had little confidence and 2.6% had no confidence whatsoever (Figure 11A, B, C; Appendix C).

Participants involved in the traditional field trip were very confident in their appreciation and understanding of for the complexity of the issue (Figure 10). Traditional field trip participants were much more confident than those involved in the virtual field trip. Thirty-three percent responded ‘very confident’ when asked about their ability to formulate and argument for or against the Day Ranch development, 53% were confident and 13% were somewhat confident. Twenty percent of those involved in the traditional field trip felt very confident in explaining the connection between the geology and the Day Ranch issue, 53% were confident and 27% were somewhat confident. Participants involved in the traditional field trip were confident in their ability to explain how geology effects the location of water in the valley, 27% were very confident, 47% were confident and 27% were somewhat confident (Figure 11A, B, C; Appendix C).

"Confidence" records participants' estimation of their understanding of the complexity of the issue, however confidence may not directly relate to their understanding of the complexity of the issue. Concept maps are used to evaluate participants' actual ability to place the concepts into a larger context and display their understanding of the complexity of the entire issue. Thirty-eight group A participants submitted a concept map following the virtual field trip, 36 group A participants submitted a concept map following completion of both the virtual and traditional trips. Seventeen group B participants submitted concept maps following the traditional field trip, 16 group B participants submitted concept maps following both the traditional and virtual field trips. Concept maps were evaluated, using a scoring rubric (Appendix B) and a comparison to an instructor concept map (Figure 14), for validity and number of linkages between concepts. Scores were given with a total of 30 points possible, 10 points for each category. A score of 30 would indicate a student closely replicated the instructor concept map and fully addressed all categories. Concept map scores show a unimodal, slightly skewed left distribution (Figure 15).

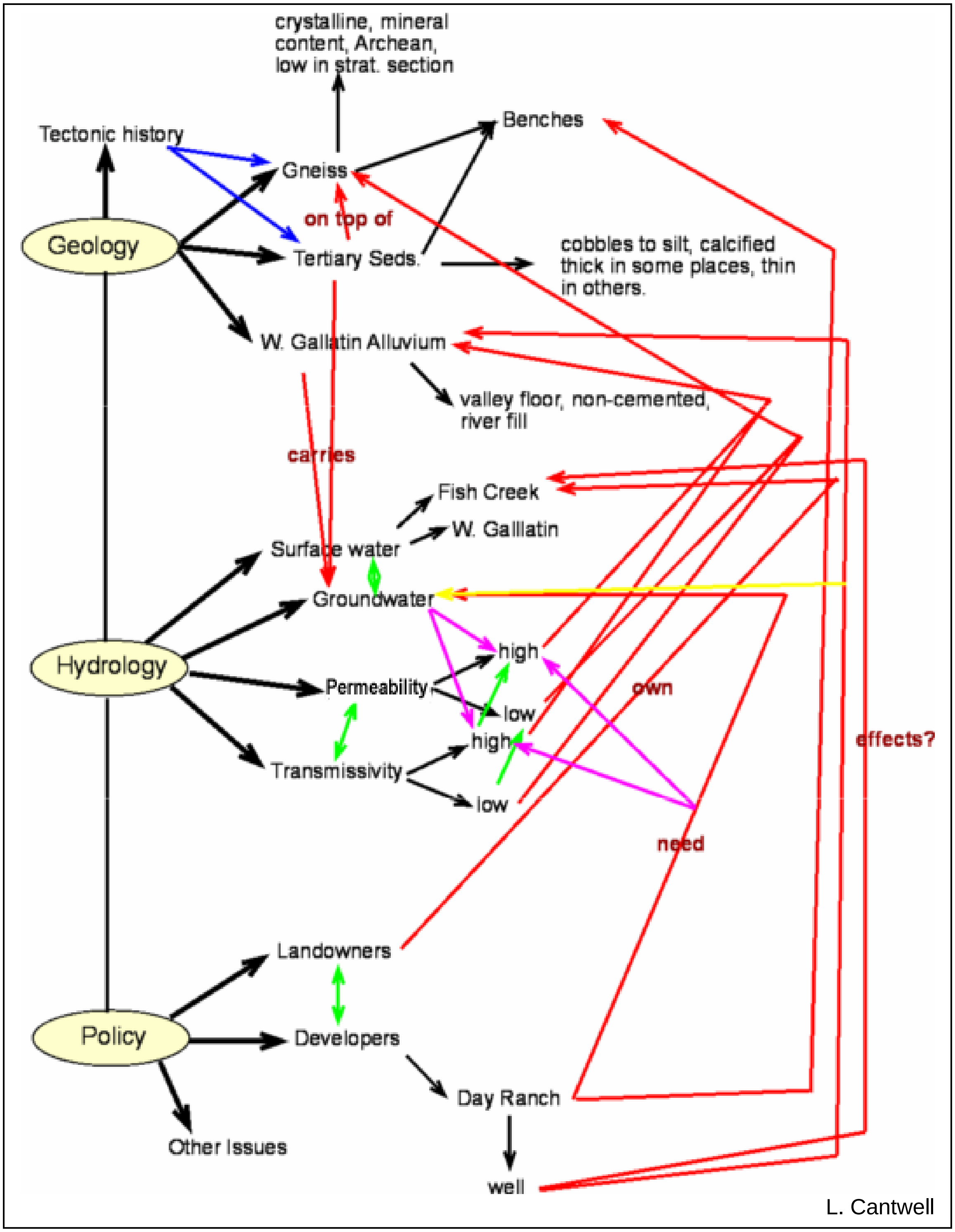


Figure 14 – Instructor concept map for the Water Wars field trip.

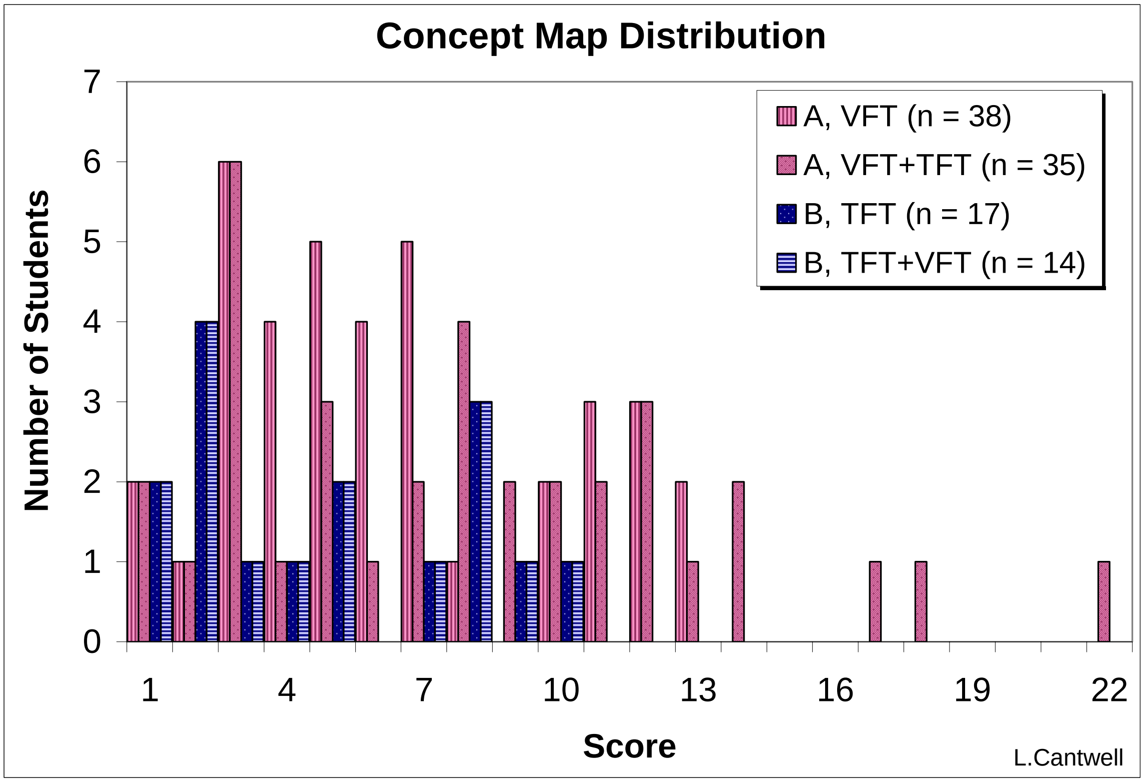


Figure 15 – Distribution of concept map scores. Each student handed in two concept maps, one following the traditional field trip and one following the virtual field trip.

Students involved in the virtual field trip showed greater ability to identify and link concepts associated with the Water Wars field trip experience. While concept maps completed following *only* the virtual and traditional field trips were of general poor quality (Table 5), the virtual field trip participants yielded higher overall concept map scores (Figure 15). Group A participants, those involved in the virtual field trip first, identified more valid of linkages between concepts (mean 1.07) than those of the traditional field trip (mean 0.76, Figure 16). Also, group A participants noted more relevant terminology in their concept maps than participants from group B (traditional field trip first; Figure 16). These differences also carried through the entire field trip experience. Group A performed higher overall as well as in the validity of linkages and terminology categories upon completion of the full experience, virtual *and* traditional field trip completed (Figures 15 and16).

Concept map results from group B are perplexing. While group B participants identify more concepts following the traditional field trip than those involved *only* in the virtual field trip (Figure 16), group B understanding seems to have diminished throughout the process. Participants involved in the virtual field trip as a post-activity scored notably lower in the number of concepts as well as slightly lower in the validity of linkages rubric category. These results suggest students were unable identify similar concepts and concept links involved in the issue upon completion of the post-activity virtual field trip. This observation will be discussed later in the study.

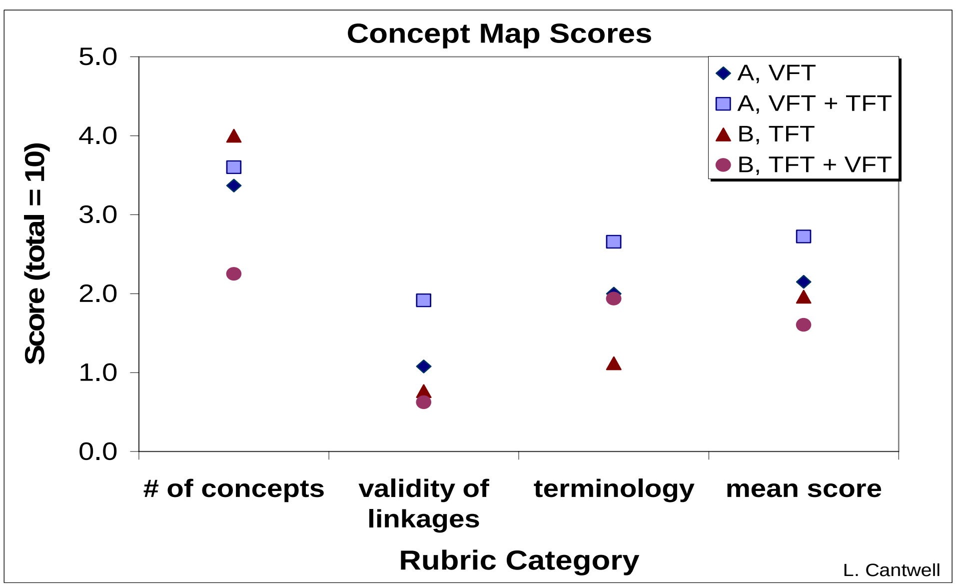


Figure 16 – Plot of concept map performance. Rubric categories are outlined in Appendix B. Mean score corresponds to the average of the three rubric categories. Each student completed two concept maps, one following the virtual field trip and one following the traditional field trip. Statistical significance of each data point found in Appendix C

Table 5 – Concept map results. All scores are out of 10 total. Complete data can be found in Appendix C.

	Group A		Group B	
MEAN	*VFT only*	*VFT + FT2*	*FT only*	*FT + VFT2*
Number of Concepts	3.4	4	3.5	2
Validity of Linkages	1.1	1	1.8	1
Terminology	2.0	1	2.6	2
TOTAL	*6.7*	*6*	*7.9*	*5*

	Group A		Group B	
MEDIAN	*VFT only*	*VFT + FT2*	*FT only*	*FT + VFT2*
Number of Concepts	3	3	4	2
Validity of Linkages	0	0	0	0
Terminology	1	3	0	1
TOTAL	*4*	*6*	*4*	*3*

	Group A		Group B	
STANDARD DEV.	*VFT only*	*VFT + FT2*	*FT only*	*FT + VFT2*
Number of Concepts	1.3	1.7	1.8	0.8
Validity of Linkages	1.6	2.4	1.3	1.2
Terminology	2.2	2.5	1.7	2.2
TOTAL	*5.1*	*6.6*	*4.8*	*5.2*

Virtual field trips as a pre or post activity: Hypothesis 4 (Table 1).

Participants involved in the virtual field trip, pre-activity, (group A) received a slightly higher mean score (63.5%) than those involved in the virtual field trip, post-activity (group B, 62.8%, Figure 13). Students participating in the virtual field trip first showed a 10.3% mean (10.3% median change) increase in knowledge from pre-test to post-test as determined by comparing the multiple choice and sketch pre-test and final write up scores. Students involved in the traditional field trip first experienced an 11.6% mean (9.9% median change) increase in knowledge from pre-test to post-test. As seen in

Figure 17, most students improved their pre-test scores after completing the virtual and traditional field trip. It should be noted that the pre-test and post-test were different assessments that were testing similar outcomes. The pre-test scores reflect students' performance on multiple choice questions and a sketch of the groundwater system. The post-test scores reflect students' performance on the write-up report. Students were expected to include information that was tested in the pre-test questions in the write-up in order to receive a satisfactory score (Appendix B). There is a possibility that students' that did not improve their pre-test scores following completion of the activity reflect the students' understanding of the assessments rather than the field trip content. As expected (Cervato and Rudd, in press), males and females performed similarly, male versus female write up scores were not statistically significant (Appendix C).

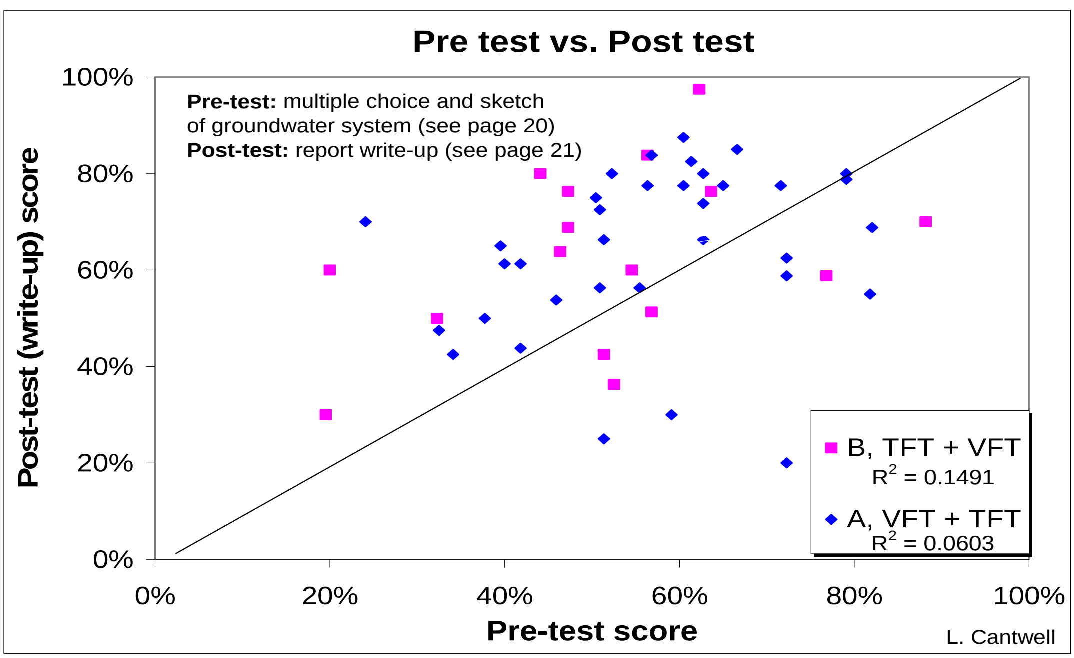


Figure 17. Linear relationship between pre-test (multiple choice and sketch questions) and post-test scores (write-up) for group A (virtual field trip as pre-activity) and group B (traditional field trip as pre-activity).

Students involved in the virtual field trip first (group A) showed an overall improvement in concept map scores, whereas students involved in the virtual field trip as a post-activity scored consistently lower in most concept map rubric categories (Figure 16, Table 4). The drop in scores may indicate those participating in the virtual field trip as a post-activity tend to disregard learning and the assessments because they already participated in the traditional field trip (which generates high confidence). This will be discussed in more detail in the following chapter.

Participants were more confident following the traditional field trip than the virtual field trip (Figure 11); however this confidence in understanding was not substantiated with student concept map or write-up scores (Figures 16 and 17). Students did not feel prepared to write their final reports following the pre-activity virtual field trip. However, following the traditional field trip pre-activity students felt much more confident in their understanding and ability to write their final reports. Twenty-nine percent of the traditional field trip participants were very confident in their understanding and performance on the field trip, 42% were confident, 26% were somewhat confident and 2% had little confidence. Roughly thirteen percent of the virtual field trip participants were very confident in their understanding and field trip performance, 39.6% were confident, 30.9% were somewhat confident, 15.0% had little confidence and 1.8% had no confidence whatsoever (Appendix C). Students felt they understood the field trip area and issue better following the traditional field trip. Twelve percent of those involved in the virtual field trip strongly agreed, 74% agreed, 9% were indifferent and 6% disagreed, while 43% of those involved in the traditional field trip strongly agreed, 50%

agreed, and 6% were indifferent. Participants involved in the traditional field trip first also felt better prepared to write their final report with all the necessary information (Figure 18). None of those involved in the virtual field trip strongly agreed they were well prepared to write their final reports following the virtual field trip, 32% agreed, 44% were indifferent and 24% disagreed. 25% of those involved in the traditional field trip strongly agreed, 56% agreed and 19% were indifferent (Table 6).

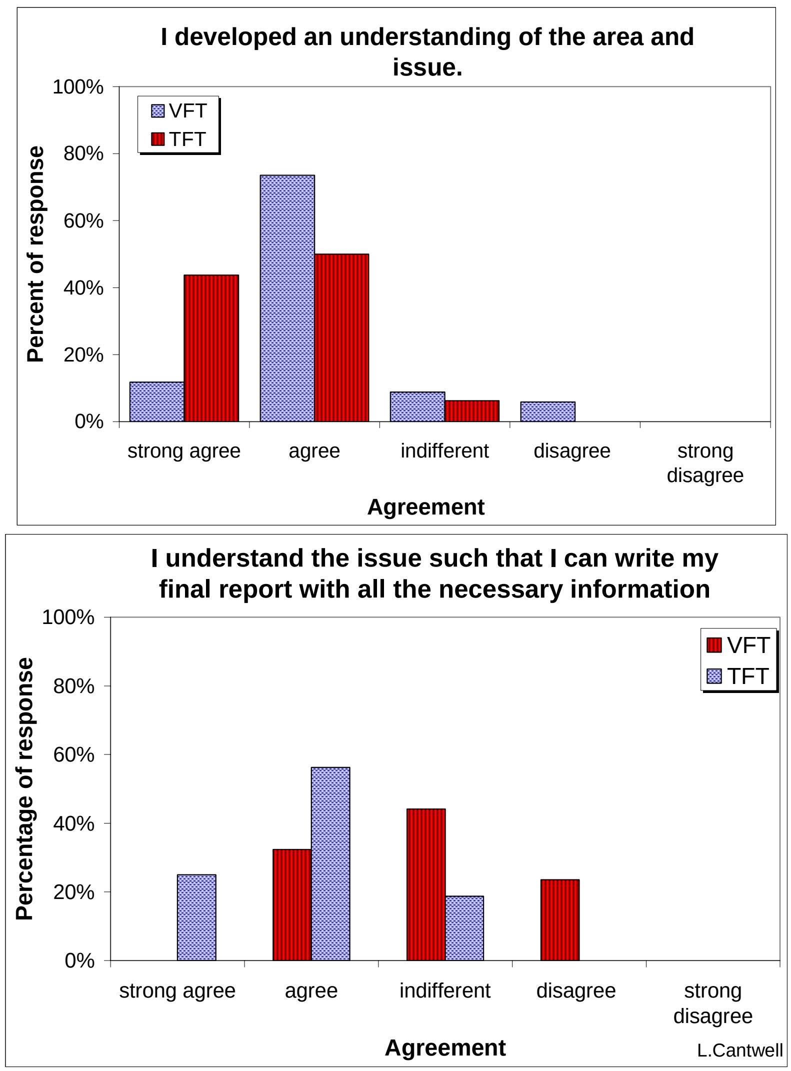


Figure 18 – Understanding and enjoyment of virtual and traditional field trips. Students feel more prepared and confident using the traditional field trip as pre-activity.

Table 6 – Enjoyment and understanding of Water Wars field trip concepts.

	1 (strongly agree)	2 (agree)	3 (indifferent)	4 (disagree)	5 (strongly disagree)
I enjoyed the virtual field trip. (Virtual)	0	13	18	0	3
Percentage	0%	38%	53%	0%	9%
I developed an understanding of the area and issue. (Virtual)	4	25	3	2	0
Percentage	12%	74%	9%	6%	0%
I developed an understanding of the area and issue. (Traditional)	7	8	1	0	0
Percentage	44%	50%	6%	0%	0%
I understand the issue such that I can write my final report with all the necessary information. (Virtual)	0	11	15	8	0
Percentage	0%	32%	44%	24%	0%
I understand the issue such that I can write my final report with all the necessary information. (Traditional)	4	9	3	0	0
Percentage	25%	56%	19%	0%	0%

The goal of this study is to evaluate the effectiveness of virtual field trips in the Earth Science curriculum. Results were collected to determine whether virtual field trips can approximate learning goals typically associated with traditional field trips such as development of observation skills, question asking and hypothesis construction skills, evaluation and use of data skills and building an appreciation for the complexity of science. Also of interest was how virtual field trips can best be used in conjunction with traditional field trips. Results were collected and evaluated to determine if virtual field trips are best used at pre- or post-activities. In the following chapter, these results will be discussed in length and used to provide suggestions for virtual field trip developers and users.

CHAPTER FIVE

DISCUSSION AND CONCLUSIONS

This chapter will discuss 1) whether virtual field trips successfully address learning goals expected from traditional field trips and 2) the most effective use of virtual field trips, if used in conjunction with traditional field trips as either a pre- or post-field trip activity.

Learning Goals

In the unfortunate event that an instructor can not logistically include a traditional field trip in his/her curriculum, it is important to understand how well a virtual field trip can establish skills associated with traditional field trip. The skills addressed in the Water Wars field trips are observation skills, question and hypothesis development, evaluation and use of data and appreciation for the complexity of the field trip problem.

Observation Skills.

Participants involved in the traditional field trip exhibit stronger observation skills than those involved in the virtual field trip ("sketches:" Figure 7, Table 1). Traditional field trip sketch scores and note detail scores are higher than those of the virtual sketch and note detail (Table 3; Appendix C). While notes tended to be messier, students included information that indicates insightful observation of their surroundings (Figure 8). Observation scores could be stronger in the traditional field trip for three reasons; 1) being outside appeals to all senses and other interests (such as biology and botany) causing students to pay attention to their surroundings and observe more, 2) a trip into the field may also invoke a sense of discovery and excitement, students are more likely to explore outcrops closely than in a controlled laboratory environment and 3) observation in the virtual environment is limited to the view which is presented by the designer making it difficult to make highly detailed observations.

Being in the field is a multi-sensory experience that is difficult to mimic on a computer. Students can hear, smell, touch and see their surroundings whereas in a virtual field trip, they may only be able to see what is on the screen and hear their instructor's commentary. Water Wars only gave the students an opportunity to see photographs, text and illustrations and converse with their computer partner and instructor. Students may absorb more details with respect to the environment if they can hear a stream running, smell the sage in the air, and feel the temperature and aridity in the air. Such observations are not necessarily recorded in sketches, but in notes with respect to the environment. Traditional field trip notebook detail scores were significantly ($p = 0.012$, 95% CI) higher than notebooks completed in the virtual environment (Figure 7, Appendix C). Students mentioned information about the surroundings as well as interesting facts they may have heard during discussions with the instructors. Students were more likely to refer to temperature, weather and climate as well as details about the rock types and outcrops they observed while on the traditional field trip. Since the field trip focuses on groundwater issues, observations regarding the aridity and climate are quite important and much easier to understand when you can feel temperatures and touch soil and plant life.

Beyond sensory input, the fact that students are actually in the *field* and immersed in the environment they are studying may motivate students to sketch and record more information than in the virtual field trip. Research suggests field trips enhance motivation (Kern and Carpenter, 1986). Field trips are exciting and students may perform better while they are in the field because of the excitement and energy associated with an excursion (Bellan and Scheurman, 1998). Several students acknowledged the excitement and motivation associated with being in the field in their final attitude surveys. Student suggested the class should have included "more field trips" and many felt the traditional field trip was one of the better laboratory exercises of the semester. Such excitement and motivation possibly translated into additional attentiveness while in the field and development of stronger observation skills.

Students involved in the virtual field trip may find the idea of a 'field notebook' unusual for, what they presume, is a laboratory assignment. Most laboratory assignments completed in the Environmental Geology course, although inquiry-based, required short answers or essay discussions. In the laboratory setting, students were unaccustomed to recording 'field' observations and therefore less likely to record careful observations in the virtual field trip. They wanted to record the correct answer and were not focused on garnering relevant information beyond the questions asked. Students also had additional virtual field trip instructions regarding drawing sketches which often controlled their observations. The virtual field trip had clickable questions that provided instructions and illustrations explaining how to complete certain tasks (Figure 5). In the case of sketches, instructions were, in some cases, a hindrance to students' ability to observe. Instructions were too prescriptive rather than descriptive and they created an environment of restricted thinking (Figure 10). Students followed the directions in a step-by-step manner and were not inclined to sketch and think creatively. Students recorded what they *thought* the instructor wanted to see rather than actual observations. Students involved in the traditional field trip had limited instruction with respect to field sketches, therefore students were not lead astray by the instructions and completed sketches that recorded accurate and unique observations. Perhaps providing brief, simple instructions and allowing the students to ask for details rather than providing step-by-step instructions up front would help students think more freely. Brief, open-ended instructions may require students to think through the information *they* identify as important to record and subsequently observe more closely in the virtual environment.

Many of the traditional sketches included information such as wildlife, recreation (i.e. fly fisherman), plants as well as the information required for the sketches (Figure 8). Traditional field notebooks sketches received significantly higher ($p = 0.006$, 95% CI) scores than virtual notebook sketches (Figure 7). In the field, students can observe aspects of the environment which interest them as well as the outcrops, rocks and surroundings that the field trip examines. Students may pay more attention to detail when they are highly interested in what they are observing. Since introductory geoscience students may not be initially interested in geology, appealing to their other interests, such as biology, may capture and focus their attention on the task at hand. In a recent study of medical students, researchers developed a successful program to teach clinical observational skills. Given the right context, students may be motivated to make better observations of the geology in a field area if they can see how those observations might influence the things they are interested in (Bransford et al., 2000). For example a student interested in fly fishing may be more inclined to make close observations in a river setting if they recognize that geology has an effect on their fishing holes. Students also make better observations when looking at something they enjoy, a river in the fly fishing example. Students observe paintings at a local art museum and then transfer those skills to clinical observation (Bardes et al., 2001). Students felt that the act of looking at something they enjoyed sparked numerous questions that helped develop strong observational skills. Perhaps students involved in the traditional field trip are doing just that, translating their observation of something they enjoy to observation of the landscape.

While students were able to make observations during the Water Wars virtual field trip, their observations were limited to what was presented as photographs, data and illustrations. In the case of the Tertiary sediment, many students mistakenly sketched a graded bed due to the perspective of the photograph provided (Figure 9 and 19). Students in the field were able to explore and view the full extent of the outcrop, noting lateral changes and differences throughout the bed, whereas students involved in the virtual field trip only had one perspective, that provided by the instructor. Panoramic photographs, 360º photograph technology and tangible hand samples may provide a more equivalent experience for students participating in virtual field trips. However, in the case of the Water Wars virtual field trip, none of these added extras were provided and therefore the virtual field trip was unable to approximate the unlimited potential of observation in the field.

Figure 19 – Students observing the Tertiary sediment in the field. Notice large extent of bed available to observe and variation and distribution of clast size and type. The view of the bed in the field is much more comprehensive than one photograph in the virtual setting.

One possible advantage to making observations during the virtual field trip is that the designer can annotate images and provide additional descriptions which allow students to learn more about an outcrop than they may on their own. For example, the clickable terms highlighted in the virtual field trip allow students to link to a geologic glossary and find definitions without referring to a textbook for information about sorting, rounding and sedimentary environment. Students were also able to click on images and find annotated images with grain size or mineralology information (Figure 20).

Figure 20 – Annotated images available to students in the Water Wars virtual field trip.

The traditional field trip road log cannot provide a seamless connection between terms and a glossary. In a traditional field trip setting, students must ask instructors or try to garner additional information from the road log to find such detailed information regarding outcrops and rock units. For a shy or unsure student, approaching an instructor is a difficult task. However, student-instructor interaction presents and opportunity to explore the use of Just-in-Time teaching strategies (Novak and Patterson, 1998; Novak et al., 1999), while not fully using the technology associated with the pedagogy. Conversations on the traditional field trip were often animated and insightful. In a discussion dominated environment, an instructor can adjust the lessons or conversation to guide students through the dynamic process of learning. Providing annotated images and interactive glossary information can help students develop content knowledge, however, it cannot successfully mimic the discussion-based environment of a traditional field trip. While providing annotated images and glossary information may help a shy student acquire valuable information, an instructor should try to interact with her students during a virtual field trip in order to take full advantage of the Just-in-Time teaching opportunities presented in a traditional setting.

The virtual field trip activity did not successfully mimic traditional field trip's ability to develop students' observation skills. It is difficult to simulate the muti-sensory, exciting traditional field trip environment with simple digital images and illustrations. The virtual environment enables an instructor to provide specific information for their students through annotated images, illustrations and prescriptive text. However, annotated images and illustrations may only help students establish a basic understanding of concepts. Students benefit from coming to their own understanding of material rather than being *told* what and how they need to understand the material (Winn, 1995). Information provided in the Water Wars virtual field trip may inhibit students' ability to think creatively and freely and therefore detract from the experience of coming to their own understanding of the problem. However, given different or less detailed information, a virtual field trip may create an environment that promotes free and creative thinking.

As technology advances, student’s observational experience will increase with respect to virtual field trip. Winn et al. (2002) found that students felt more present in the field when they are immersed in an environment, wearing virtual reality helmets and interacting with the virtual environment, rather than working on a desktop. Technology such as interactive and three dimensional Geowall (2004) and other three dimensional software such as INTERFACE (Aiken, 2004) allows students to immerse themselves in the field without leaving the laboratory; however such technology is, for the most part, limited in availability. Future desktop virtual field trips may begin to address the difficulties of producing an authentic virtual data gathering experience and provide students with a virtual field trip that teaches them to evaluate and use data effectively as they become more interactive. Continued study of learning using virtual field trips will be necessary to determine the value of advanced visualization technology.

Hypothesis Development and Questioning.

Numerical results suggest the virtual field trip was successful at establishing question asking and hypothesis development skills (Figure 7, Tables 1 and 3), however the difference in hypothesis scores was not statistically significant ($p = 0.577$, 95% CI). While it may be possible to establish a cause and effect relationship between learning on a virtual field trip and the development of question asking skills, it is difficult to determine the connection between the virtual field trip and hypothesis development skills.

Virtual field trip notebook scores related to question asking were significantly ($p = 0.007$, 95% CI) higher than those from traditional notebooks (Figure 7). Hypothesis development virtual field trip scores were numerically stronger (mean 6.5/10, Table 3) than those of the traditional trip (6.2/10, Table 3), and *if* that difference is not the result of chance, the success of the virtual field trip is due to three possible influences 1) the fact that students are focused, less overwhelmed by the complexity of a natural environment and on task throughout the entire virtual field trip, 2) students in the virtual field trip view their field notebook as an assignment to turn in, 3) students feel less confident about their ability and therefore are more inclined to ask numerous questions and ruminate upon the problem further or 4) students posed outwardly better questions and developed better hypotheses because of the restricted information and controlled environment of the virtual field trip.

While the traditional field trip invoked more confidence in question asking (Figure 11), students involved in the traditional field trip did not write sophisticated questions in their notebook (Figure 7). Roughly 1/3 did not pose *any* questions during the traditional field trip. This phenomenon could be explained by the fact that students were unable to develop questions and pose hypotheses while in the field; however other research suggests traditional field trips are successful in teaching question asking and hypothesis skills (Hawley, 1997). It is more likely the lower scores can be attributed to the arrangement of stops in the traditional field trip. The students were asked to pose questions during the lunch break discussion of the Day Ranch issue. The conversation on both traditional field trip days was lively and engaged, many students asked insightful questions and seemed to be pondering the problem thoroughly. Students may have felt satisfied with the questions discussed during the conversation and believed it was unnecessary to write the questions down in the field notebook (primarily for their own use). They may have also lost focus and by-passed posing questions because they were busy eating lunch.

A field trip can also be a very intense and complex learning environment for many students (Falk et al., 1978; Orion and Hofstein, 1991; 1994). While most students participate in field trips during their academic careers, a field trip can be a very overwhelming environment in which to learn. This potentially overwhelming nature of learning in the field may make students unable to synthesize their observations and thoughts into cohesive and insightful questions/hypotheses in the field. While students feel confident regarding their ability to ask questions (Figure 11), they did not record comprehensive, detailed questions in their notebooks (Figure 7). Perhaps the concise and orderly nature of the information provided in the virtual field trip reduced the overwhelming complexity often associated with learning in the field and helped students organize their thoughts into relevant and succinct questions.

Not only is the laboratory setting less overwhelming and more familiar, GEOL 102 students were also accustomed to completing computer-based laboratories and submitting assignments associated with those exercises. When asked to complete the virtual field trip in the familiar laboratory setting, students may have been more inclined to record their answers and turn in a complete virtual field notebook, even though they were informed notebooks would not be graded. However, students seemed more inclined to treat their traditional notebooks as only “theirs,” not something they would submit to a governmental agency, and failed to record details, such as questions and hypotheses, they felt was unimportant. Because students are more familiar with fully completing exercises in the laboratory setting, they may be more inclined to fully address *every* task presented during the virtual field trip and subsequently provide more detailed questions and accurate hypotheses.

Students were less comfortable with their understanding and ability to ask questions following the virtual field trip, however their concept map performance exceed that of students involved in the traditional field trip (Figures 11, 14, 15). Research suggests that students learn more and develop stronger skill sets when pushed outside their perceived level of understanding into the zone of proximal development, a level of development where students are pushed beyond their perceived potential by an instructor or higher achieving peer (Vygotsky, 1978). Students may be able to develop stronger question asking and hypothesis testing skills during the virtual field trip *because* they are not highly confident. With guidance, they are pushed beyond their comfort level and develop a better understanding of how to ask questions than if they perform to *their* perceived potential. The virtual field trip may successfully take students outside their comfort zone, into a cognitive position where they are able to learn more.

Students involved in the virtual field trip were able to write more correct hypotheses than those involved in the traditional field trip, however results were again not statistically significant. Both groups were asked to use well data and field observations in conjunction with their understanding of geology to develop a hypothesis regarding an unconformity in the valley. Students involved in the virtual field trip had the well data and photographs readily available on the web linked trip. Students involved in the traditional field trip could only refer to their notes. Once students in group B, virtual field trip as a post-activity, obtained the information from the virtual field trip, they were able to develop very strong hypotheses (Appendix C, Figure 21). However, it was only after they had access to the virtual field trip that their hypotheses improved. If the difference between scores cannot be attributed to chance, having accurate information to which to refer may have a strong influence on students' ability to develop hypotheses. While students were to develop hypotheses during both field trips, there is a possibility that both groups put additional thought into hypotheses following the field trips. If this was the case, students involved in the virtual field trip had the advantage of accurate information and ample time to refer to that information via the World Wide Web.

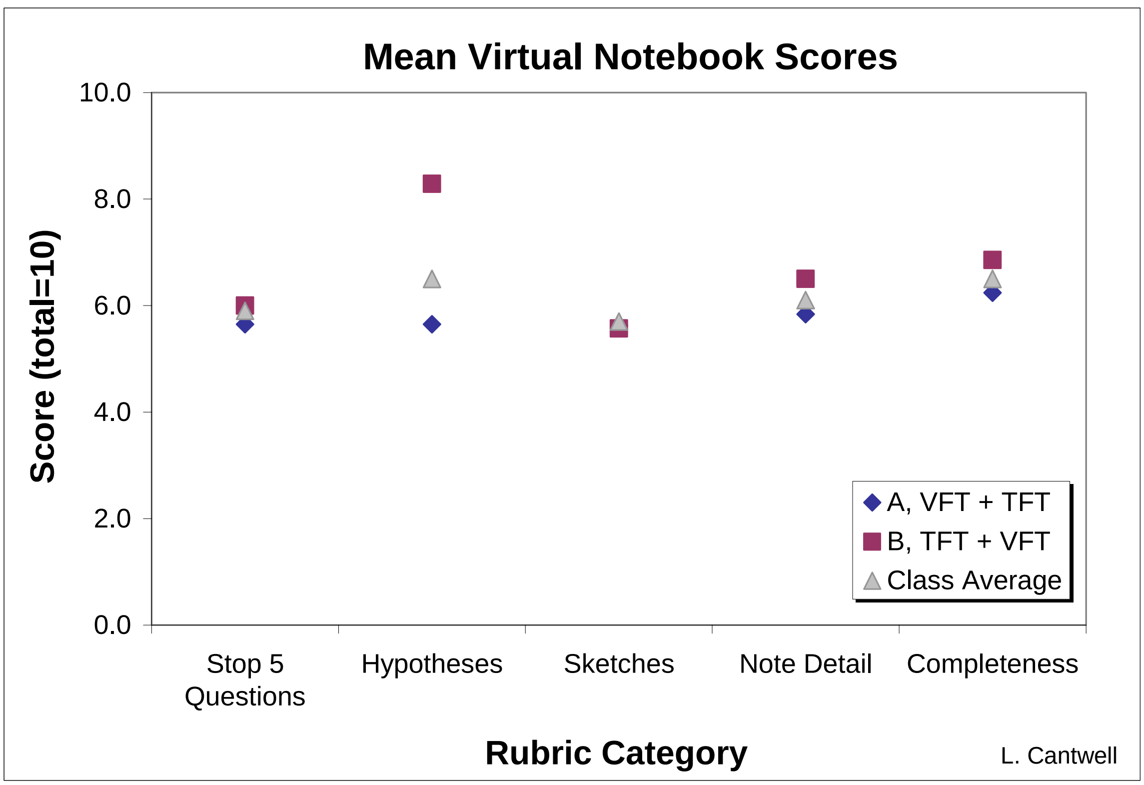


Figure 21. Mean virtual field notebook scores. Significance information in Appendix C.

If students did produce their hypotheses during the field trips, the strength of hypotheses developed during the virtual field trip could reflect, again, the students' ability to focus on the field trip task. Students involved in the traditional field trip were asked to write their hypotheses in the van between stops. Many students believe the van ride is a 'rest' from tasks they have to perform at each stop. Participants may have been too distracted with social conversations and interactions to complete thoughtful hypotheses.

Students' notebook results suggest a clear distinction between their ability to pose questions and formulate hypotheses in their field notebooks and their ability to do so in their virtual field notebooks (Figure 21). The virtual field trip was able to help students ask relevant questions and pose reasonable hypotheses regarding the Day Ranch problem. In the laboratory environment, students were able to focus on *only* the task at hand, either posing questions or writing hypotheses, and were not distracted by their surroundings or the lure of social interaction. They are familiar with completing tasks in the laboratory and are therefore more inclined to fully complete the assignment regardless of if the assignment is graded. The distillation of information in the virtual field trip also reduced the overwhelming natural complexity students experience in the field. Information gathered during the virtual field trip is limited to facts, images, photographs and text provided by the designer. Therefore, questions and hypotheses developed during the virtual field trip reflect *only* the information provided by the designer/instructor. Students were able to pose outwardly better results, however they may have been restricted in terms of creativity and independent thinking. The controlled environment of the virtual field trip may help students focus and develop more precise questions and hypotheses, however they may only arrive at questions or hypotheses related to the information provided in the virtual field trip, rather than thinking about numerous possibilities related to the complexity of the issue. Nevertheless, virtual field trips are successful as the traditional field trip in helping students develop question asking and hypothesis construction skills.

Evaluation and Use of Data.

The traditional field trip was successful helping students understand how to evaluate and use data in geologic controversies (Figure 12, Table 1, Appendix C). The traditional field trip afforded students the opportunity to sample and record data for themselves. Since they were able to stand in the stream, measure discharge, see the channel geometry and tributaries, they were able to develop some questions about the validity of data presented in the controversy. The traditional field trip let students experience the inherent uncertainty involved with collecting geohydrologic data. Students involved in the traditional field trip are more confident in their ability to use and evaluate data because they had a chance to collect data first hand (Figure 11). They had a chance to evaluate how to collect the data and the methods established for collecting stream discharge, therefore feel more confident using and evaluating data throughout the field trip experience. The traditional field trip provides an active learning environment, traditionally more successful at conveying ideas of complexity and uncertainty (Eby et al., 2002)

In a passive virtual field trip environment, such as Water Wars, students are given data measured by the instructor and descriptions of how the data was gathered. Students felt more comfortable using their data in an argument, however felt like they wanted to gather more data (Figure 12). Students are less likely to question the methods and validity of the data because they did not collect the data on their own and actually experience uncertainty while collecting data. Essentially, students "trust" the data they have been provided and are comfortable using it in a scientific argument. It is difficult for students to learn how to properly evaluate and use data in such an environment. The hands-on approach with respect to data collection in the traditional field trip helps students understand the uncertainty and error involved in collecting data. They are more likely to be skeptical of data involved in an argument if they experience uncertainty of data collection first hand. Perhaps streaming video depicting data collection with a detailed description of the surroundings and variables involved could help the virtual field trip approximate the hands-on experience of the traditional field trip. However, until technology can allow students to fully experience data collection in the "field," it is unlikely a virtual field trip will be able to closely approximate a traditional field trip with respect to evaluation and data use skills.

<u>Appreciation for the complexity of the issue</u>.

Concept map results suggest the virtual field trip in *conjunction* with the traditional field trip established a strong appreciation for the complexity of the Day Ranch issue and an understanding of topics related to groundwater (Figure 16; Appendix C). However, as a stand alone activity, the virtual field trip was able to convey the complex nature of scientific issues and help students gain an appreciation for that complexity (Table 1). Students produced stronger concept maps that accurately represented the complexity of the Water Wars problem (Figure 16), however they felt less confident in their ability to do so (Figure 11). Perhaps their lack of confidence contributed to their appreciation for the complexity of science. They did not feel fully confident in their understanding and may have been inclined to examine the problem deeper, discovering the inherent complexity of science. The virtual field trip provided just enough information that students' learning with respect to the complexity of the Water Wars problem was not stifled (reflected in Figure 11), however it apparently provided enough support for students to succeed in developing an understanding of the issue (as seen in Figure 16). The virtual field trip was able to *scaffold*, providing the right amount of support for students to achieve higher levels of learning (McKenzie, 1999), the complex scientific problem and helped students slowly develop an appreciation for the complexity of science in general.

In some cases instructions and details were somewhat prescriptive, however with respect to the big picture, the virtual field trip provided just enough information to help students learn to appreciate the complexity of science. Students were provided with terminology, read accurate and complete information from each stop, 'take' the field trip again and again until they fully understand the complexity of the issue and reflect on the activity. Through the World Wide Web, students were given an unlimited amount of time to master the subject and fully appreciate how all aspects of the problem were connected. Most students spent the full two hours given to complete the virtual field trip in laboratory and many indicated they would return to the activity following the laboratory session. Students had the opportunity to return to and retake the virtual field trip in order to develop a deeper understanding of the concepts and ideas presented in the activity. If students are given enough time to develop an understanding of the problem and process the information they are given, they will be able to master the initial concepts and transfer that information into bigger picture context (Bransford et al., 2000). There is no guarantee that students took advantage of the unlimited amount of time to complete and return to the Water Wars virtual field trip, however, the higher scores suggest the virtual field trip provided some sort of advantage in developing an understanding for the complexity of the Day Ranch issue.

Not only can the virtual field trip provide students with unlimited time to master concepts, students can click back and forth between images, information and data from, for example, stop one (depicting the modern river depositional environment) to stop three and four (depicting ancient river deposits and their juxtaposition to crystalline bedrock). This mobility between stops helps students develop a complex web of understanding and information and ultimately an appreciation for the complexity of science. In the traditional field, students take notes at each stop and can refer back to those notes; however they must rely on mental images of outcrops and environments for comparison rather than actual photographs. The traditional field trip may instill the notion continuity by driving from one stop to another and being able to see the topography change; however students are not given the free mobility between stops that is available in the virtual field trip. While the traditional field trip presents a different kind of holistic view of the problem in a traditional field setting, the ability to return to previous stops, intrinsic in all virtual field trips, provides strong support for developing an appreciation for the complexity of science.

Conclusions: learning goals.

While the Water Wars virtual field trip was not entirely successful at tackling certain learning goals, there is value in using the virtual field trip as part of Earth Science curriculum (Table 7). While it is difficult for students to make unique and comprehensive observations, students can draw from valuable terminology, definitions and image annotation while participating in the virtual field trip. For shy or reserved students, a less interactive learning environment may be beneficial for learning. The virtual field trip also takes place in a less distracting environment that helps students focus and fully address the tasks required. Class discussions and conversations and the field setting itself may make students less likely to record questions and hypotheses whereas, virtual field trips take place in a controlled setting where students are focused solely on the trip, their notebook and recording answers. The accessible nature of the virtual field trip allows students to refer to the trip *after* they have completed it in class. Students can go back, review what they learned at one stop, then click forward and see how that relates to another stop. They may also review the field trip after the designated laboratory session and round out any information they may be unsure about when completing later assignments. Built in scaffolding can help all students develop a strong appreciation for the complexity of science. While a virtual field trip does not provide a perfect replica of traditional field trips, there are definite strengths to addressing specific learning goals typically associated to learning in the field, in a virtual setting.

Table 7. Summary Hypothesis Number 2: Virtual field trips can equally address the learning goals expected from traditional field trips

Hypothesis	Response	Rationale
Students learn the same observation skills as they would on a traditional field trip.	NO	Being outside appeals to all senses, outdoor experience invokes sense of discovery and excitement not replicated in a virtual environment and observation in virtual environment limited to designer's perspective which can lead to misconceptions and difficulty making correct observations.
Students learn the same question asking and hypothesis development skills as they would on a traditional field trip.	YES, in some cases better	Controlled setting of virtual field trip creates focused environment for students to concentrate and because students feel less confident, they are more inclined to ask questions to gain confidence. However, creativity and free thinking may be diminished due to controlled setting.
Students learn to evaluate and use data on virtual field trips as they would on a traditional field trip.	NO	The hands-on approach to data collection creates more skepticism with respect to actual data and use of that data. Students were able to collect data and experience uncertainty involved in data collection.
Students can develop an equal appreciation for the complexity of scientific issues and the natural world as they would on a traditional field trip.	YES	Embedded scaffolding in virtual field trip helps students achieve higher order thinking. Students were able to review material, skip from stop to stop and return to the 'field' after they have completed the virtual field trip in the web-based environment of the trip. This mobility and accessibility promoted development of skill.

Virtual field trips as a pre or post activity.

In many cases instructors still have the opportunity to utilize traditional field trips in their curriculum. If they are able to overcome the difficulties of conducting traditional field trips, they may want to consider using virtual field trips as an activity to complement a traditional field trip. While there are many advantages to using the virtual field trip as a pre-activity, such as reduced novelty space (Orion and Hofstein, 1994) and better preparedness for the complexity often encountered in the field, there are some identified disadvantages to using the virtual field trip first. Students may experience diminished discovery and motivation with respect to the field. With both advantages and disadvantages associated with using the virtual field trip as a pre-activity, it is important for instructors to consider the specific goals of the field trip prior to choosing how to use a virtual field trip.

The virtual field trip establishes the terminology, knowledge (Figure 16, Appendix C), and an understanding of the sequence of stops seen on the on the traditional trip (Table 1). Students were exposed to the cognitive, geographic and psychological components of the field trip, prior to leaving the laboratory. Orion and Hofstein (1991) suggest that reduction of these factors, all part of the *novelty space* associated with learning in the field, creates a successful field learning experience. Results suggest many students, especially those with less knowledge with respect to groundwater, benefited from the reduction of novelty space provided by the pre-activity virtual field trip (Figure 17, Appendix C). Prior to going into the field students asked valuable questions regarding the issue, developed and appreciation for the complexity of the issue and begin to understand the information necessary to evaluate data and make observations in the field (Figure 16). A virtual field trip allows students time to master the content at their own pace (by reviewing via the World Wide Web) and focus on developing knowledge, gathering relevant information and completing tasks in a distraction-free environment. Most students agreed that participating in the virtual field trip first helped “give [them] a better understanding about what to expect on the [traditional] field trip” and that it provided “good background prior to the real field trip.” Research suggests mastery of the original subject (geohydrology, geology, etc.) is an important and vital step in students’ ability to successfully transfer that knowledge to a better understanding of the complex issue at hand (Bransford et al., 2000). By using the virtual field trip as a pre-activity, students are able to learn about the issue and area's geology prior to the exposure to the complex field environment.

Since Water Wars was a successful pre-activity, one would expect that using the virtual field trip as a post-activity would not have a detrimental effect on student learning. However, concept results suggest that the group B students actually *lost* knowledge (Table 5) with respect to geohydrology and the Day Ranch issue. Students identified fewer concepts involved in the issue and made fewer valid links between concepts (Figure 17). Since it is difficult to comprehend loss of knowledge, there is a more reasonable explanation for this phenomenon. Group B completed the virtual field trip on the final laboratory session of the semester. Students were required to complete the concept map in class prior to leaving and rushed through the process rather than completing a concept map that accurately reflect their understanding of the Day Ranch issue. Students' performance during the virtual field trip mirrored their concept map performance. While their notebook scores were identical (Table 3), most students completed the virtual field trip in one hour, one hour faster than group A (virtual field trip as pre-activity). Students rushed through the virtual field trip for two possible reasons 1) they were anxious to complete their final laboratory of spring semester and 2) they had a false sense of mastery, they had already completed the traditional field trip, which instills confidence in knowledge, and considered virtual field trip as merely repetitive.

The experimental design required the virtual field trip and traditional field trip to be as close to identical as possible. Given two similar tasks, students that had already participated in the traditional field trip felt confident, perhaps falsely, in their understanding of the problem and rushed through the virtual field trip failing to see the value in revisiting the same stops for a second time. Considering the concept results and confidence logs, it is probable that students were in a rush to complete their final laboratory session of the semester. However, many students acknowledged the virtual field trip "repeated a lot of [the questions] from the field trip" and the "virtual field trip was too repetitive after being outside." Students may have felt so confident in their understanding of the issue following the traditional field trip, they felt there was no added value in completing the virtual field trip.

Using the virtual field trip as a post-activity does add value to their experience, despite students' perception. Students involved in the traditional field trip as a pre-activity had higher confidence regarding their knowledge and abilities (Figure 11), however that confidence was not substantiated in their write-up scores (Figure 17) or to a greater extent, their concept map scores (Figure 16). The traditional field trip may instill a false or misplaced sense of confidence that can prevent them from seeing the value in a reflective activity following the concrete learning activity, the traditional field trip. Reflective activities are a necessary and important part of the learning cycle. Reflection allows students to refine their understanding of a subject or problem and modify any information which they did not fully understand or conceptualize in the actual activity (Kolb, 1984). Students actually experience lower confidence while taking the virtual field trip (Figure 11) which may help them better understand the complex nature of the Water Wars problem. In any learning activity it is imperative to have an activity or discussion dedicated to reflection. While the virtual field trip in this study worked best as a pre-activity, it is important to note that, given a slightly modified (from the original traditional field trip) and complementary virtual field trip, students may begin appreciate the complexity of an issue and learn from the reflective virtual field trip activity.

There are disadvantages associated with using the virtual field trip as a pre-activity. While the virtual field trip successfully reduced novelty space, some research suggests the novelty of a field trip is its most positive feature (Kaspar, 1998). Some students are excited and motivated by the newness of experiences in the field. Using the virtual field trip as a pre-activity can reduce this sense of discovery for some students. A small number of group A (virtual field trip as pre-activity) students “felt the actual field trip was tedious, as [they] had already gone over everything.” By design, the virtual field trip was a replica of the traditional field trip. Students felt the sense of discovery associated with participating in a traditional field trip was diminished by participation in the virtual field trip. They felt the field trip was a “bit boring” and would have rather seen the outcrops and environment in the field and then used the virtual field trip as a review. Traditional field notebook results reflect this boredom and inattentiveness (Figure 6 and 22). In their attitude survey, many group B (virtual field trip as post-activity) students indicated they would not include the virtual field trip in the field trip experience; however, as seen in Figure 21, many of their notebook results indicate that they benefited from participating in the virtual field trip. They were able to develop better hypotheses, questions and had more complete and detailed notes.

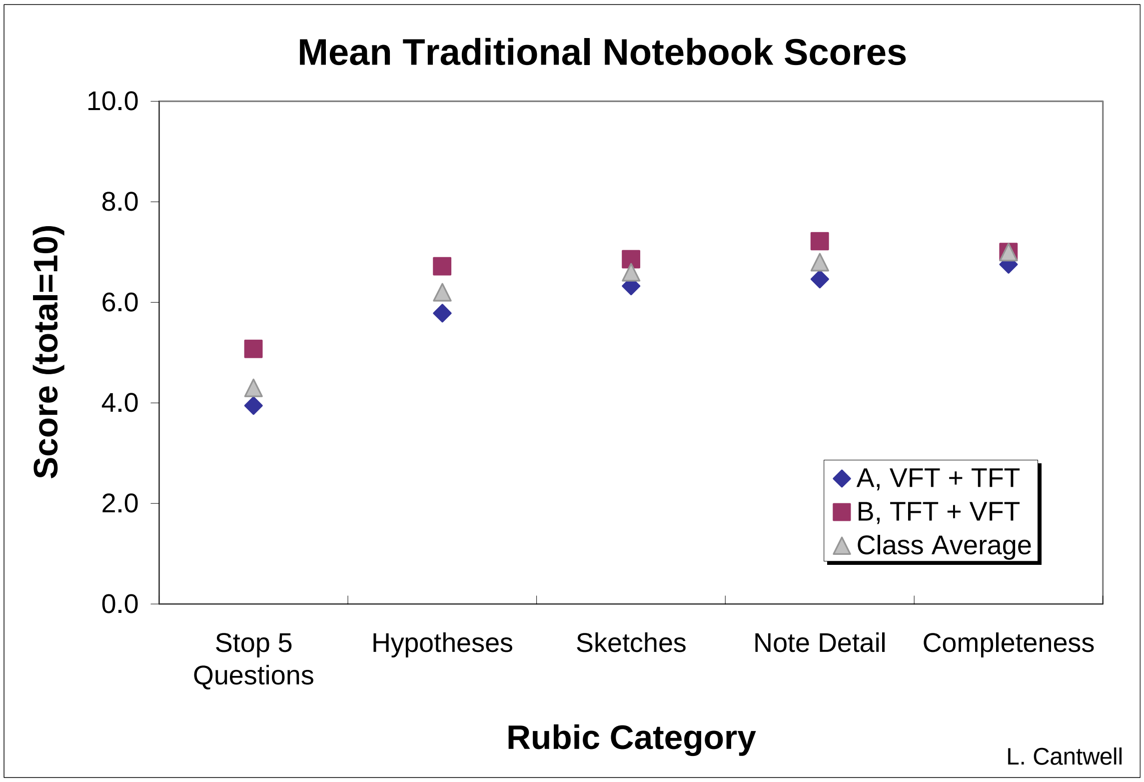


Figure 22. Traditional notebook scores. Significance information in Appendix C.

Results from this study suggests, given two identical field trip experiences, the virtual field trip as a pre-activity is more effective than the virtual field trip as a post-activity (Table 1 and 8). However, learning goal results suggest that instructors need to clearly identify the goals of the field trip experience prior to making a decision regarding when to use a virtual field trip in conjunction with a traditional field trip.

If an instructor is interested in having students' master concepts, knowledge and information about a certain location, using the virtual field trip as a pre-activity is ideal. If an instructor is interested in a field trip invoking a sense of discovery and wonder about the natural world then using a virtual field trip activity as a post-activity may be the best. In practice, the virtual field trip as a post-, reflective activity should be a unique activity that facilitates reflection, transference of knowledge and skills. Perhaps the use of a slightly modified virtual field trip itinerary will be more effective than an exact replication of the traditional field trip itinerary.

Table 8. Advantages and disadvantages related to use of virtual field trip as a pre- or post-activity and suggestions for use.

	Advantages	Disadvantages	Suggestions for use
VFT as Pre-activity	✓ Reduces novelty space ✓ Allows time for mastery of subject matter	✓ Reduces discovery and wonder associated with seeing things for the first time in the field	✓ Learning Goal = Content mastery and knowledge development
TFT as Pre-activity	✓ Students experience fully wonder of being in the field	✓ Instills high confidence in understanding and students do not focus on the importance of reflection	✓ Learning Goal= Instilling sense of discovery and wonder about natural world

Conclusion: Pre vs. Post Activity.

Virtual field trips are a valuable addition to Earth Science curriculum, however it is important to identify specific activity goals and objective prior to establishing whether a virtual field trip functions best as a pre- or post-activity. If an instructor is interested in establishing content knowledge and understanding of an area, a virtual field trip works best as a pre-activity. If an instructor is interested in invoking a sense of discovery and wonder about the natural world, a modified virtual field trip may function best as a post-activity. In both cases, an instructor must be aware of students' attitudes and reaction to each component and be willing to adjust the exercises to best suit the needs of the students.

The Water Wars virtual field trip was more successful as a pre-activity (Table 9). It helped students establish a solid understanding of the geology, hydrology and policy involved in the Day Ranch controversy. This virtual field trip helped to reduce novelty space related to participating in a field trip. It helps establish an understanding of concepts, terminology, the trip itinerary goals and expected outcomes. With the virtual field trip, students essentially have an opportunity to master the subject prior to being asked to transfer the knowledge to the complex issue. The controlled atmosphere reduces distractions often associated with traditional field trip and helped them concentrate and address certain learning goals that take additional thought and attention.

Table 9. Summary Hypothesis 4: The virtual field trip is more effective as a pre-activity than as a post-activity when used in conjunction with a traditional field trip.

Hypothesis	Response	Rationale
Students have a better understanding of the entire issue using the virtual field trip as a pre-activity.	YES	Virtual field trip reduces novelty space and allows time for mastery of content at varying speeds
Students develop more confidence in their understanding of the issue suing the virtual field trip as a pre-activity	NO	Learning in virtual environment is new and does not instill as much confidence as traditional field trip. Confidence in a traditional environment may be false or misplaced confidence because it does not correlate with actual ability.

Using Water Wars as a pre-activity had its disadvantages as well. While students may have established better content knowledge regarding the area, using the virtual field trip as a pre-activity, for some students, took away the sense of discovery and excitement of being in the field. As an instructor, it is important to be aware of students' attitude and approach to the traditional field work following the virtual field trip. It is possible that a small subset of students may feel they have established an understanding of the content and fail to see the value of participating in a traditional field component of the exercise. While most students are excited to participate in a traditional field trip, an instructor should clearly articulate the additional and deeper understanding students can gain participating in a traditional field trip after completion of a virtual field trip.

Virtual field trips and traditional field trips achieve different, yet complimentary goals. Traditional field trips invoke a sense of discovery and wonder with respect to the natural world. Students are able to make unique and high-quality observations about the environment and understand the importance and reasons to be analytical about using data. The virtual field trip can reduce students' novelty space and provide a simple, clear, information-rich and distraction free environment in which students can learn. An instructor should be aware of these complimentary goals and identify the reasons for using both activities in a learning experience.

In this study, using the virtual field trip as a post-activity was not a successful learning activity. Students rushed through the virtual field trip, which took place on the last day of the semester, and did not see the value in completing the reflective activity. The traditional field trip instilled high confidence with respect to learning and ability; however, many students' concept maps did not show a clear understanding of the concepts and Water Wars problem and failed to substantiate student confidence. Students, confident in their ability to articulate knowledge, are less likely to focus during the post-activity virtual field trip and do not appreciate the value of reflecting on what they have seen and learned in the field.

Whether an instructor chooses to use a virtual field trip as a pre-activity or post-activity will depend on the instructor's specific goals and objectives for the exercise. However, once he/she has identified those goals, the virtual field trip can fit into the curriculum very nicely as a pre (if the instructor is interested in content mastery) or post (if the instructor is interested in discovery) activity.

Student Attitude and Confidence

Students' attitude is intrinsically linked to their learning in any environment. "Positive change in student attitude can mean positive gains in understanding and science literacy," (Jach and Cervato, 2004 p. 28). While some students enjoyed the virtual field trip, most were indifferent (Hypothesis 5, Table 1). Many seemed to relate to Water Wars as just another laboratory assignment. All students said they enjoyed and learned from the traditional field trip. Research substantiates that students, for the most part, enjoy time off campus, learning in a foreign and exciting environment (Bellan and Scheurman, 1998). Perhaps as technology advances and the virtual field trip environment becomes more interactive, student attitude toward virtual field trips will change.

The traditional field trip setting instills much higher confidence, perhaps false (shown in concept map results; Figure 18), in students than the virtual environment (Hypothesis 3, Table 1). Perhaps students feel they learn more and understand more following immersion in the field. Since that sense of immersion was not successfully achieved in the Water Wars virtual field trips, students failed to feel as confident in their abilities following completion of the virtual field trip. For many students, field trips have been a part of classroom activity since early grade school. Students feel comfortable and excited about learning on a field trip, it is something they have done for numerous years. Virtual field trips are an emerging learning environment and it may take time for students to become comfortable and confident learning in such an environment. While virtual field trips may not instill as much confidence as a traditional field trip, diminished confidence in learning is not always a negative aspect of a learning environment.

Students often learn best when they are unsure of their knowledge and understanding of a topic.

Suggestions for Designers and Instructors

Virtual field trips are an exciting emerging teaching tool in the Earth Sciences. While much is still unknown about the use and effective design of virtual field trips, this study does provide information that supports some suggestions for amateur virtual field trip designers and instructors.

Amateur Designers.

Designers must be aware of the difficulties associated with depicting travel through space in a virtual media. On a virtual field trip, many students have trouble locating themselves on digitized maps and in space. A designer must make location information clear, concise and very explicit to attempt to mimic traveling through space during a traditional field trip. Simple animations, clickable maps and annotation of maps and photographs can help students understand how they have traveled from one stop to another.

Designers must also be aware of the audience. If the virtual field trip is to be a stand alone exercise (meaning students are not expected to use additional resources to understand the concepts), designers should include *any* and *all* information needed to understand the context of the field trip. Virtual field trips have the distinct advantage of being connected to the World Wide Web. Designers should take advantage of the WWW and use it to convey necessary information to their users Designers should be cautious about providing too much information for students to wade through. Designers should keep in mind the idea of scaffolding and provide information students need to be supported in learning, but avoid including *all* possible information.

Designers must be aware of the perspective from which they are portraying information. Photographs should show outcrops and landscapes from several perspectives such that the designer can reduce any misinterpretations by limiting vantage points (such as the Tertiary sediment example). If 360º or panoramic photography is available, designers may choose to include images that students can manipulate and maneuver rather than static digital photographs.

Finally, designers should try to design a virtual field trip that appeals to all learning styles. Visual, textural, even audio and kinesthetic (in the form of mouse manipulation) information should be included.

Instructors.

It is vital for instructors to establish a clear set of goals and objectives for which a virtual field trip is to be used. Instructors must establish what they expect their students to learn from the virtual field trip and tailor the use of such a trip to those expectations. Instructors should also realize that virtual field trips do not appeal to all learning styles. They should be attentive to students' needs and aware that some students may struggle with learning in a virtual environment.

Conclusions

This study was able to establish how well virtual field trips can approximate learning goals and skills often associated with traditional field trips as well as make some recommendation regarding the use of virtual field trips as pre- or post-activities. While this is an encouraging start on developing a comprehensive understanding of student learning on virtual field trips, there are several questions still unanswered.

1. Is Water Wars more effective than a typical groundwater laboratory exercise?
2. Is a comprehensive pre-field trip lecture/discussion equivalent to using a virtual field trip as a pre-activity?
3. Are virtual field trips more effective with certain learning styles?
4. How does advanced technology (i.e. 3D imagery, 360º photography) influence the effectiveness of virtual field trips?

In order to fully understand the value of virtual field trips in the Earth Science curriculum, future research is necessary.

Virtual field trips are a valuable and emerging tool in geoscience education. The Water Wars virtual field trip successfully addressed learning goals that require focused attention and basic environmental input, such as question asking and hypothesis development. Water Wars acted as an effective prelude to its traditional field trip counterpart, effectively reducing the novelty space often associated with learning in the field. As technology advances and designers and instructors learn more about creating and using effective virtual field trips, virtual field trips may become an adequate alternative to traditional field experience.

REFERENCES CITED

Aiken, C., 2004, Acquisition and use of 3D photorealistic models for virtual field trips and exercises [Online] http://serc.carleton.edu/files/NAGTWorkshops/visualize04/aiken_essay.pdf [accessed on August 2004]

Bardes, C.L., Giller, D., Herman, A.E., 2001, Learning to look: developing clinical observation skills at an art museum: Medical Education, v. 35, p. 1157-1161

Bellan, J.M., Scheurman, G., 1998, Actual and Virtual Reality: making the most of field trips: Social Education, v. 62, no. 1, p. 35-40

Bransford, J.D., Brown, A.L., Cocking, R.R. and others, 2000, How People Learn: brain, mind, experience and school: Washington D.C., National Academy Press, 374 p.

Brody, M., Tomkiewicz, W., 2002, Park visitors' understandings, values and beliefs related to their experience at Midway Geyser Basin, Yellowstone National Park, USA: International Journal of Science Education, v. 24, no. 11, p. 119-1141

Campbell, D.T., Stanley, J.C., 1963, Experimental and Quasi-Experimental Designs for Research: Boston, MA, Houghton Mifflin Company, 84 p.

Cantwell, L., 2003, Water Wars; A Look a Gallatin County Water Controversies: [Online] http://gemini.oscs.montana.edu/~geol102/spring2004/Field%20Trip%20Stuff/Webpages/WATER%20WARS.HTML

Cervato, D., Rudd, J.A., 2004, Predicting student success in introductory geology using diagnostic testing: Journal of Geoscience Education (in press)

Compiani, M. and Carneiro, C.D.R., 1996. The Didactic Roles Played by Geological Excursions, *in* Stow, D.A.V., et al., eds., Geoscience Education and Training; in schools, Universities, for Industry and Public Awareness: Rotterdam, A.A. Balkema , p.233-242

Cooke, M.L., Anderson. K.S., Forrest, S.E., 1997, Creating Accessible Introductory Geology Field Trips: Journal of Geoscience Education, v. 45, no. 4, p. 4-9

Cooray, P.G., 1991, Fieldwork: An essential component of geoscience education and training: Episodes v. 14, no. 4, p. 337-340

Curry, G.B., Burton, C.J, 2002, Use of field trips in Earth Sciences: Environmental & Earth Sciences Learning and Teaching Swap Shop [Online] http://www.herts.ac.uk/natsci/Env/ches/newches/past/SwpshpAbsApril02/Curry.pdf [accessed on April 2003]

Dixon, S.A., Custer, S.G., 2002, Lithostratigraphic and hydrogeologic units of the Gallatin Local Water Quality District, Gallatin County, Montana: [Online] http://mapserver.giac.montana.edu/maps/319a/stratcolumn.pdf [accessed November 2004]

Dunning, J.D., Onesti, L.J., Christopherson, R., Kaveney, D., Friel, M., 2001, The next generation of virtual field trips; making the virtual field trip more responsive to pedagogical goals of traditional field trips: Geological Society of America Abstracts with Programs, v. 32, no. 7, p. 203

Dreamlink, 2003, Web design guide: [Online] http://www.dreamlink.com/design1.shtml [accessed on October 2003]

Ebert-May, D., 2004, Assessment: What are the questions? What evidence do we accept? ESA Workshop: [Online] http://www.first2.org/resources/wrkshopmaterials/workshop_table.html [accessed on October 2004]

Eby , J.W., Herrell, A.L., Hicks, J., 2002, Reflective Planning, Teaching and Evaluation: K-12; 3rd Edition: Upper Saddle River, NJ, Merrill Prentice Hall, 328 p.

Edelson, D.C., 2001, Learning-for-Use: a framework for the design of technology supported inquiry activities: Journal of Research in Science Teaching, v. 38, no. 3, p. 355-385

Falk, J.H., Martin, W.W., Balling, J.D., 1978, The novel field-trip phenomenon: adjustment to novel settings interferes with task learning: Journal of Research in Science Teaching, v. 15, no. 2, p. 127-134

Folkomer, T.H., 1981, Comparison of Three Methods of Teaching Geology in Junior High School: Journal of Geological Education, v. 29, p. 74-75

Gaskin, S., 2003, The impact on the learning and teaching experience of the removal of fieldwork from academic programs in the GEES subject areas; University of Plymouth, Pedagogic Research and Development Database: [Online] http://www.pedres.net/cgi-bin/searchspec.pl?terms=23 [accessed on April 2003]

Gevock, N. 2001a, Day Ranch team makes pitch to neighborhood: Bozeman Daily Chronicle, 19 May 2001 [Online] http://bozemandailychronicle.com/articles/2001/05/19/news7712.txt [accessed on August 2004]

Gevock, N. 2001b, Day Ranch project shot down 3-0: Bozeman Daily Chronicle, 27 June 2001: [Online] http://bozemandailychronicle.com/articles/2001/06/27/news6534.txt [accessed on August 2004]

Gevock, N., 2004a, Golf project developers withdraw well applications, Bozeman Daily Chronicle, 13 April 2004: [Online] http://bozemandailychronicle.com/articles/2004/04/13/news/002dayranchbzbigs.txt [accessed on August 2004]

Gevock, N., 2004b, Day Ranch lawsuit against county settled for $10,000, Bozeman Daily Chronicle, 15 April 2004: [Online] http://bozemandailychronicle.com/articles/2004/04/15/news/golfbzbigs.txt [accessed on August 2004]

Gill, R., 1997, A student's first encounter with fieldwork – making it an effective learning experience, *in* Proceedings Examples of Good Practice in Earth Science Learning and Teaching: Fieldwork, UK Geosciences Fieldwork Symposium: [Online] http://www.gees.ac.uk/essd/field.htm [accessed on August 2003]

Geowall Consortium, 2004, An introduction to GeoWall: [Online] http://www.geowall.org [accessed on August 2004]

Google, 2004, Geology Virtual Field Trips: [Online] http://www.google.com [accessed on August 2004

Greater Yellowstone Coolition (GYC), 2001, By turning down a controversial development proposal, Gallatin County commisioners uphold popular will and smarth growth: [Online] http://www.greateryellowtone.org/winchester_developments.html [accessed on June 2003]

Hawley, D., 1997, 'Being There;' A short review of field-based teaching and learning: experience *in* Proceedings Examples of Good Practice in Earth Science Learning and Teaching: Fieldwork, UK Geosciences Fieldwork Symposium: [Online] http://www.gees.ac.uk/essd/field.htm [accessed on August 2003]

Hurst, S.D., 1998, Use of 'virtual' field trips in teaching introductory geology: Computers and Geosciences, v. 24, n. 7, p. 653-659

Jach, J.Y, Cervato, C., 2004, Attitude toward learning science of students in introductory geoogy courses: Teaching Earth Sciences, v. 29, no. 2, p. 28-31

Karabinos, P., Stoll, H.M., Fox, W.T., 1992, Attracting students to science through field exercises in introductory geology courses: Journal of Geological Education v. 30, p.302-305

Kaspar, M.J., 1998. Factors affecting elementary principals' and teachers' decisions to support outdoor field trips. [Ph.D. thesis]: Austin, University of Texas-Austin.

Keller, W.D., 1963, Field work: our scientific birthright: Journal of Geological Education v. 11, no. 4, p. 119-123

Kern, E.L., Carpenter, J.R., 1986, Effect of Field Activities on Student Learning: Journal of Geological Education, v. 34, p. 180-183

Kolb, D. A., 1984, Experiential learning: Experience as the source of learning and development: Englewood Cliffs, NJ, Prentice Hall, 288 p.

Kuvaas, B., Kaufmann, G., 2004, Impact of mood, framing and need for cognition on decision maker’s recall and confidence: Journal of Behavioral Decision Making, v. 17, p. 59-74

Lacina, J.G., 2004, Designing a virtual field trip: Childhood Education, v. 80, no. 4, p. 221-223

Lopushinsky, T., Besaw, L., 1986, Field experiences for non-science students: Journal of College Science Teaching, v. 15, p. 21-24

Mackenzie, D., Stowell, J., 1997, TRIADS applications: computer based assessment of recent field experience *in* Proceedings Examples of Good Practice in Earth Science Learning and Teaching: Fieldwork, UK Geosciences Fieldwork Symposium: [Online] http://www.gees.ac.uk/essd/field.htm [accessed on August 2003]

McKenzie, G.D., Utgard, R.O., Lisowski, M., 1986, The Importance of Field Trips; a geological example: Journal of College Science Teaching, p. 17-20

McKenzie, J., 1999, Scaffolding for success: [Online], From Now On, the Education Technology Journal, v. 9, no. 4, http://www.fno.org/dec99/scaffold.html [accessed on November 2004]

Melim, L.A., 2004, Virtual Field Trips for Undergraduate Sedimentary Geology: two birds with one stone: Geological Society of America, Annual Meeting, Abstract with Programs, v. 36, no. 6, p. 364

Montana Department of Environmental Quality (MDEQ), 2004, Non-Point Source Water Quality Standard Operating Procedures; Surface Flow Measurements: [Online] http://www.deq.state.mt.us/wqinfo/monitoring.SOP.pde.11-04.pdf [accessed on April 2004]

Montana State University, 2004, University Catalog.: [Online] http://www.montana.edu/wwwcat/ [accessed on May 2004]

Natural Resources Canada, 2004, Geoscape Victoria: [Online] http://www.pgc.nrcan.gc.ca/geoscapevictoria/groudwater.htm [accessed on August 2003]

Nix, R.K., 2001, Virtual field trips; the next best thing to being there (and sometimes better!): Geological Society of America, Rocky Mountain Section; Abstract with Programs v. 33 no. 5, p. 3

Novak, G., Paterson, E.T., 1998, Just-in-time-teaching: Active learner pedagogy with WWW: *in* Proceedings International Conference on Computers and Advanced Technology in Education: [Online] http://webphysics.iupui.edu/JITT/ccjitt.html [accessed on October 2004]

Novak, G., Gavrin, A., Christian, W., Patterson, E., 1999, Just-In-Time Teaching; Blending Active Learning with Web Technology : New Jersey, Prentice Hall Publishing, 188 p.

Orion, N., Hofstein, A., 1994, Factors that Influence Learning during a Scientific Field Trip in a Natural Environment: Journal of Research in Science Education, v. 31, no. 10, p. 1097-1119

Orion, N., 1993, A Model for the Development and Implementation of Field Trips as an Integral Part of the Science Curriculum: School Science and Mathematics, v. 93, no. 6, p. 325-331

Orion, N., Hofstein, A., 1991, The Measurement of Students' Attitudes Toward Scientific Field Trips: Science Education, v. 75, no. 5, p. 513-523

Orion, N., 1989, Development of a High-School Geology Course Based on Field Trips: Journal of Geological Education, v. 37, p. 13-17

Pestrong, R., 2000, Geology-the sensitive science: Journal of Geoscience Education, v. 40, p. 333-336

Reynolds, S.J., 2004, Arizona Geology: [Online] http://geology.asu.edu/~reynolds/home.htm [accessed on October 2004]

Reynolds, S.J., Tewksbury, B., 2004, Concept Sketches: using student-generated annotated sketches for learning, teaching and assessment *in* Proceedings Teaching Structural Geology in the 21st Century: NAGT Cutting Edge Workshop, Presentation S1B: [Online] http://serc.carleton.edu/NAGTWorkshops/structure04/schedule.html [accessed on October 2004]

Rooney, M., 2002, Enrollments Soar at Colleges of All Types; For Some of Them, That's a Mixed Blessing: Chronicle of Higher Education v. 49, no. 10
Science Education Resource Center (SERC), 2004, Starting Point: Teaching Entry Level Geoscience, Role-Playing: [Online] http://serc.carleton.edu/introgeo/roleplaying/index.html [accessed on October 2004]

Slater, T.F., 2003, Classroom Assesment Techniques; performance assessment: Field-tested Learning Assessment Guide: [Online] http://www.flaguide.org/cat/perfass/perfass1.htm [accessed on April 2003]

Smart Webby, 2003, Web Design Tips; useful tips for effective web design: [Online] http://www.smartwebby.com/web_site_design/webdesign_tips.asp [accessed on October 2003]

Smith, A.J., 1996, Fieldwork in Crisis: current and future provision, pp. 581-587 *in* Stow, D.A.V., et al., eds., Geoscience Education and Training; in schools, universities for industry and public awareness: Rotterdam: A.A., Balkema

Spicer, J.I., Stratford, J., 2001, Student perceptions of a virtual field trip to replace a real field trip: Journal of Computer Assisted Learning, v. 17, p. 345-354

Stevenson, S., 2001, Discover and create your own field trips: Multimedia Schools, v. 8, no. 4, p. 40-47

Thornbury, H., 2004, Confidence Logs: Learning Technology Dissemination Initiative Evaluation Cookbook: [Online] http://www.icbl.hw.ac.uk/ltdi/cookbook/confidence_logs/printable.pdf [accessed on April 2003]

Topozone, 2002, Montana Topographic Map: [Online] http://www.topozone.com [accessed on August 2002]

University Space Research Association (USRA), 2003, What is Earth Systems Science?: [Online] http://www.usra.edu/esse/essonline/ [accessed on April 2003]

U.S. Census Bureau, 2002, Gallatin County, Montana; People QuickFacts: [Online] http://quickfacts.census.gov/qfd/states/30/30031.html. [accessed on December 2003]

Winn, W., 1995, Learning in Interactive and Immersive Environments: [Online] http://faculty.washington.edu/billwinn/papers/nime.html [accessed on November 2004]

Winn, W., Windschitl, M., Fruland, R., Lee, Y., 2002, Features of Virtual Environments that Contribute to Learners' Understanding of Earth Science: [Online] http://faculty.washington.edu/billwinn/aera_02/narst.doc [accessed November 2004]

Vuke, S.M., Berg, R.B., Lonn, J.D., Kellogg, K.S., 1995, Geologic map of the Bozeman 30' x 60' quadrangle, Montana, Montana Bureau of Mines and Geology scale 1:100,000, 2 sheets

Vygotsky, L. S., 1978, Mind in society; The development of higher psychological processes: Cambridge, MA, Harvard University Press, 176 p.

Yellowstone National Park, 2004, Windows into Wonderland: [Online] http://www.windowsintowonderland.org/ [accessed on August 2004]

Zeilik, M., 2003, Classroom Assesment Techniques; concept mapping, Field-tested Learning Assessment Guide: [Online] http://www.flaguide.org/cat/minutepapers/conmap1.htm [accessed on April 2003]

APPENDICES

APPENDIX A:

TRADITIONAL FIELD TRIP FIELD GUIDE

Water Wars: A Look at Gallatin Valley's Water Controversy

Road Log and Questions

Introduction

The purpose of this field trip is to explore the controversy surrounding ground and surface water rights in Gallatin Valley. With so many exciting topics to discuss in geology, why do we care about water controversies? Water is a hot issue in environmental science and geology. We all need water to live, as future homeowners we will need to understand water laws, and water controversies plague many communities around the nation and the world.

Water may seem like an unlimited resource. However, the amount of total water usable by humans is less than one percent. Water is actually a scarce and precious natural resource. It is important to understand how we use our groundwater and freshwater both throughout the United States and in our own community.

Montana is predominantly rural, landowners, developers and county commissioners deal with water right issues on a daily basis. Virtually all of Montana's population is served by private groundwater or surface water supplies. Because most of Montana's water is privately owned, there are many heated and perplexing arguments usage and ownership of streams or groundwater. Gallatin Valley is no exception. On this field trip you will be exploring one of those controversies and discovering the unique way geology is used as a weapon in the debate.

Gallatin Valley is considered the fastest growing county in the state of Montana, seeing a 4.3% population increase between 2000 and 2002 (AP, 2003). While there are many good things that come with development, a growing economy and a more diverse community, there are also problems that arise such as questions regarding urban sprawl, environmental impact, and water rights. **The Problem:** A development company submitted a proposal for a 2,800 acres subdivision with an equestrian center, clubhouse and 18 hole golf course. Water for the subdivision and golf course is being pumped from a well on the valley floor up to benches. The well is near the head of a spring creek called Fish Creek. Water in Fish Creek is owned by three landowners.

- Data produced by the development company suggests that pumping from the well does not effect water levels in Fish Creek
- Data produced by the landowners suggests that pumping from the well removes water from the Fish Creek, violating the water rights

So the argument rests in the fact that one side believes water rights are being violated by pumping at the Day Ranch well. While the other believes that pumping at the well has no effect on Fish Creek. On this field trip you will examine this current controversial issues dealing with water rights and land use. The question we will address is:

What are the land-use and development implications of development of the Day Ranch subdivision and golf course?

Keep in mind these are relevant issues your community leaders are dealing with on a daily basis. Not only is this issue and important community issue, it is related to issues you may have to deal with in the future. Water is essential for life, it is important for you to understand what controls water. Someday you will buy a home and water is something you will need. It will be nice to know a bit about where to find it and what controls where it is located and how much is available!

While on the field trip we will be examining several environmental questions and probably coming up with more questions to ask. As you complete the tasks required of you during this trip, think about how humans and the natural environment interact. How is the hydrologic system vulnerable with respect to human impact? How are humans vulnerable to the state of the hydrologic system? How is the location of water affected by geology? And how does that affect humans? Also think about the Day Ranch controversy and how geology is being used in the argument. Does the available data give you an answer to the water rights question? Can it be manipulated depending on your agenda? What kind of evidence is definitive evidence when trying to answer the water rights questions? There is a lot to think about on this trip. Your main goal is to formulate a hypothesis with respect to each question and then use the data you gathered in the field to support that hypothesis.

Learning Goals

Geologic/Hydrologic Goals

- Gain an understanding of ground water flow and aquifer properties
- Understand how geology influences the location of groundwater
- Develop some idea of the evolution of geology and geohydrology of Gallatin Valley
- *Determine if the pumping data from Day Ranch well provides evidence that pumping will violate the Fish Creek water right*
- Develop some question asking skills and develop student's ability to used scientific method
- Gain the ability to critically evaluate the validity of data and evidence and the consequences of interpretations or conclusions
- Spatial Reasoning, understand what you are looking at without seeing it directly
- Gain an appreciation of the complexity of these issues
- Learn to visualize the invisible.

Field Trip Itinerary

Stop 1: Gallatin River

Time: 25 minutes

At this stop we will be exploring the formation of alluvial aquifers, determine the Gallatin river's role in shaping the valley and determine the how much groundwater can be held by alluvial aquifers.

First thing you should do is draw a sketch of your surroundings. Just make a profile of the valley to get a feel for the lay of the land. Indicate on your profile where you would like to build a golf course.

1. Look at the geologic map and the Gallatin River, which rock unit is the Gallatin River flowing over?
2. Standing at on River Road, looking south, draw a sketch of the valley. Indicate where YOU think the best place to build a golf course would be.

Next, make a sketch of the river channel, think about how grain size and river flow are related.

3. Now, looking at the river, draw a sketch of the river. Make a note of the location of specific grain sizes and what controls the location of grain size across the river. =

4. How will the distribution of grain size affect groundwater transport in the future?

Stop 2: Gneiss

Time: 25 minutes

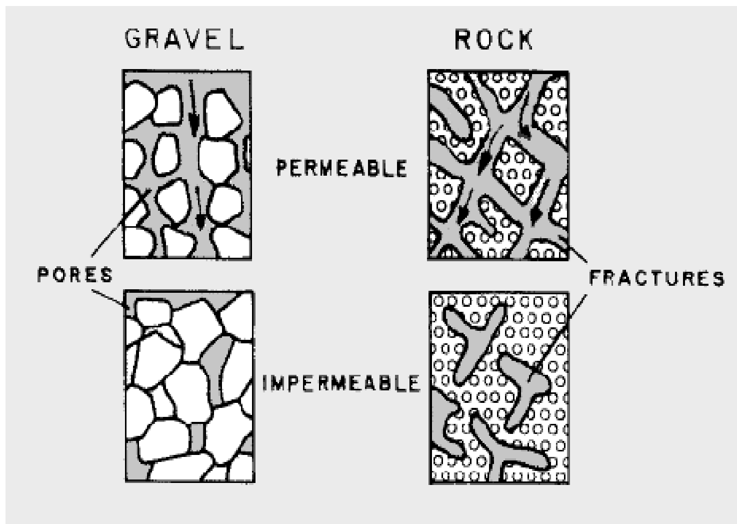
At this stop we will look at the crystalline gneiss and how water is stored in that crystalline rock.

Pick a representative spot on the outcrop and draw a sketch of the outcrop. On your geologic description, include as much detail as possible, color of minerals, size, porosity etc.

1. Sketch the outcrop. Pick a spot that is representative of the rock. Include a scale, thickness and any other relevant information to describe the outcrop.
2. Write a geologic description of the rock. Note the mineral type (if you don't know minerals, note color, shape etc.), porosity, and other relevant information to describe the rock.

Compare and contrast the vegetation on the left and right side of the road.

3. Compare and contrast the vegetation covering the West Gallatin Alluvium (Left) and the Gneiss (Right).
4. How might this reflect the groundwater capacity of each unit?



Water can be stored in rocks in two main ways, in pores and in cracks. Look at the aquifer map; you will see that the gneiss is called a "possible aquifer." Could water be stored in those cracks? Despite the fact that the gneiss *may* have water storage, it probably doesn't yield water like the West Gallatin Alluvium. This might cause a problem when trying to find water in the Gallatin Valley. Where else might you see the gneiss? On similar benches? What if it isn't there? What might that mean? Look south at the next bench down the road, do you think the surface rock is gneiss? It is not!

5. Write a hypothesis that might explain why you are standing next to gneiss at this stop but can look across the valley and see a different kind of rock at the same elevation

Stop 3/4: Tertiary Sediments/ Rolling look at rocks—the contact!

Time: 25 minutes

At this stop we will examine the ground water capacity of the Tertiary sediments and explore what type of depositional environment may have produced such a unit. We will also continue to explore the idea of *paleotopography* and tectonic movement in the Valley.

Because events in geologic history happen over long periods of time, it is often necessary to use our imagination to determine the historical environment that deposited old units. In Stop 1 we talked about the principle of uniformitarianism*, we can use this principle and our imagination to determine a likely depositional environment for sedimentary units.*

You will need to sketch the white chalky unit and make a geologic description of the rock.

6. Write a geologic description of the rock unit. Be sure to include grain size, grain shape and a sketch of the rock unit.
7. Imagine you are standing on this very spot in the Tertiary age (about 70 million years). Remember in Stop 1 we saw the river depositing a gravel unit with areas of silt and sand. Describe the depositional environment.
   - Are you feet wet?
   - If so, are you treading water or just standing in water?
   - Are you near a river, lake, ocean?
   - What else might you see in the area?
   - How much energy is in the system?

Ok, if you look on the left side of the road, you will see the gneiss like you saw at stop 2. From what you see here, in relation to what you saw at stop 2, think about what the top of the gneiss might be doing (is it a flat slab or an undulating surface?)

8. Look at the contact, consider previous stops and your surroundings. Draw a sketch of what you think it looks like.

Stop 5: Day Ranch Overlook

Time: 30 minutes

At this stop we will explore the Day Ranch controversy and try to understand how geology plays into the arguments.

This stop gives us a good look at the valley. If you look south, in the distance you will see a higher bench just before the entrance to Gallatin Canyon. That is where Day Ranch is proposed to be built. Think about the kinds of rock we have seen at the last two stops (this is what is underneath the benches), and answer the following question.

9. If you were a geologist for the consulting company hired to determine the water potential at Day Ranch, what questions might you be asking yourself? Would you be concerned about the groundwater potential for the Day Ranch bench?

The Day Ranch also owns land on the valley floor. This is the West Gallatin Alluvium.

Using your Topographic Map and Surficial Geology map, determine what rock unit the Day Ranch owns on the valley floor. Using your other maps, Is it an aquifer or aquitard? What is the transmissivity?

10. Is it a "better" aquifer than the Tertiary sediments found on the bench?
11. Which aquifer would you, as a consulting geologist, suggest the Day Ranch use?

The question is not *if* the West Gallatin alluvium can yield enough water for the golf course, but rather who owns the water rights and are those water rights being violated?

The West Gallatin River Alluvial Aquifer yields an excellent amount of water and holds ample water for municipal, irrigation, domestic and stock use (Custer, 1999). In this area, the water is used primarily for stock use and irrigation. Most of the water rights in the area of pre-1900 and all of the surface water (creeks and ditches) belong to someone.

Surface and Groundwater Water Right Holders Involved in the Day Ranch controversy:

- 3 landowners own 1881 and 1883 water rights on Fish Creek.
- Day Ranch owns groundwater rights from the West Gallatin Alluviual Aquifer.

Day Ranch pumps water from their well in the West Gallatin Alluvial Aquifer. During this pump test, water is removed from Fish Creek, a spring creek belonging to 3 downstream landowners. The developer's pump test suggest that the impact from the Day Ranch project is minimal. They suggest that the water they are pumping is groundwater for which they own water rights. The landowners' pump test suggests pumping water to the Day Ranch will violate the downstream 1881 and 1883 water rights. They suggest the groundwater Day Ranch is pumping comes to the surface at Fish Creek and therefore pumping groundwater out of the West Gallatin Alluvial Aquifer effects the downstream water rights. There are several issues that come into question here and their answers all rest in the data.

What does the law actually say? Check out the DNRC website if you would like to explore water right laws in Montana.

- ✓ Does pumping at the Day Ranch well truly affect downstream water rights?
- ✓ How does the interaction between groundwater and surface water affect the results from pump tests?
- ✓ Did the time of year affect the pump test results? Will it have an effect on ground and surface water if pumping takes place year-round?
- ✓ Consider where the pumped water is going. Will it ever arrive back in the aquifer? If so how long will it take?

Bottom Line:
How will the proposed Day Ranch project affect the surrounding natural and human systems?

Stop 6: Fish Creek

Time: 30 minutes
At this stop we will take a stream gauge measurements, assess the validity of data and determine how data should be used in legal arguments.

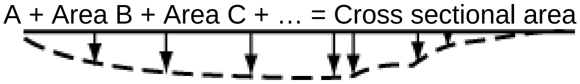
You are NOT going to make the measurements so ignore the questions below. I just want you to consider what might factor into measurements of stream flow you might make at this point on the creek. Would the measurement be representative of yearly streamflow in Fish Creek? Why or Why not?

The center of the Day Ranch controversy is Fish Creek, a small spring creek, with its spring on the Day Ranch property. Downstream Fish Creek water rights belong to three land owners. The property owners are concerned that the Day Ranch well (if pumped to support the golf course and community) will deplete the Fish Creek water supply, the W. Gallatin Alluvial aquifer and possibly the Gallatin River. The developers suggest that pumping for their use will not exceed the developers' water right. Both sides of the argument are using presumable similar data to support their hypotheses, yet they are arguing different sides of the story.

We will be determining Fish Creek discharge using the Floating Stick Method. We will measure the cross sectional area of the stream (ft^2) and then determine the time it takes for a tennis ball to move over a measured distance. Assuming the cross section is consistent over the measured distance we will find discharge by:

Cross-sectional area (ft) X speed of water (ft/s) = Stream discharge (ft^3/s)

12. Pick a section of the stream that is fairly uniform (flow and cross-section). Extend the tape measure across the cross section. One student should measure the depth of the stream at specific distances from one of the stream bank and we will record the data.
    - ✓ Area A + Area B + Area C + … = Cross sectional area



13. Measure a distance above the cross section and time how long it takes for a tennis ball to move through that distance. This measurement gives you speed.
14. Calculate the stream discharge in your field notebook (in cfs).
15. Compare this measurement with the stream discharge for Gallatin River.
16. Would you use this data in your argument? Why or why not? What other data would you like to have?

Stop 7: Other Considerations

Time: 5 minutes

Arguments for:	Arguments against:
• High quality and accommodating development "raises the ball" for all subdivision applications in the County where no zoning exists.	• traffic impacts; congestions, safety, speed
• 90% of the land will remain open space	• More effective to preserve open space rather than develop it.
• economically positive , increases tax base and benefits the community as a whole	• labor to maintain the golf course and homes will produce low paying jobs not benefiting the community
• the subdivision is better than the alternative	• protect and maintain agricultural land
• developers share concerns with wildlife management, water rights holders, noxious weed management, etc.	• negative impact on critical wildlife habitat winter range important to bears, wolves, deer and elk
• "can't put a fence around Montana," use this as an opportunity of guide development in the proper direction	• places high demand on services; fire, school, police force
	• does not comply with Gallatin County Master Plan

Assignment

You are a geologist hired to gather data, formulate an argument and present your findings in a lawsuit trial brought against Gallatin County by the Day Ranch developers. Your goal is to produce the following:

- Address **ALL** the questions in the field guide.
- Create a field notebook. Remember, this could be used as evidence in the lawsuit, so make sure you label your drawings and take neat and legible notes!
- As an expert witness, a geologist, develop argument regarding the decision of rejection of the Day Ranch development

In your report you might want to address the following:

1. What data is relevant to this lawsuit? Is it viable data?
2. What data will the developers be using to support their argument? Is that data viable?
3. How does the geologic history of the Gallatin Valley play into this lawsuit?
4. How is the geology in the area controlling groundwater? Can I explain this, in everyday terminology, to a jury?
5. Is there efficient water to maintain the Day Ranch golf course?
6. Who else might I want to consult to help support the argument?
7. What questions still need to be answered before we are certain the outcomes of development?

Include:

- ✓ Description of the Archean gneiss; geologic description and history
- ✓ Description of the Tertiary sediment; geologic description and history
  highlight the relationship between gneiss and sediment.
- ✓ Description of where water is located
- ✓ Discussion of the availability of water on the proposed golf course land

APPENDIX B:

ASSESSMENT TOOLS

PRE-TEST

The following is the pre-test for the up-coming field trip experience. You will be asked demographic information and questions regarding the content of the field trip experience. Please answer each question to the best of your ability. Your answers to the following questions will NOT affect your Geology 102 grade. ***Do NOT put your name on the sheet; include ONLY code name and group letter.***

Part I: Demographic information

Code Name ______________________________ Group Letter _________

M____ F____

Age ___

Freshman___ Sophomore___ Junior___ Senior___ Graduate___ Non-Degree___

What is your major?

Where are you from originally (what do you consider hometown)?

How long have you lived in Bozeman?

Have you taken other geology/geography courses? Y__ N__ At MSU? Y __ N__

Have you ever been on an off campus field trip? Y___ N___
If so where?

Have you ever participated in a virtual field trip? Y___ N___

Do you own a computer? Y___ N___
If no, how many hours do you spend a week working on an on-campus computer?

What is percentage of lecture do you attend?

How much time do you spend reading/studying the text book?

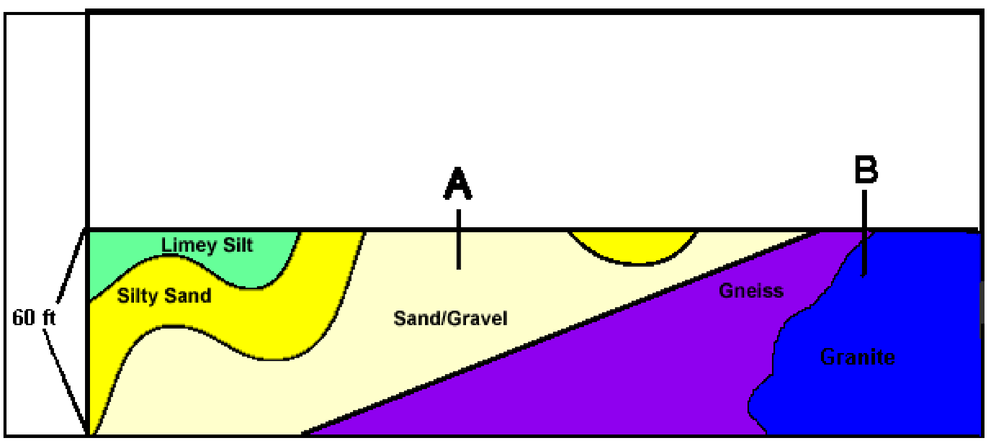
Part II: Content Knowledge

1. Draw the groundwater system. Include as much detail as you can (10 minutes max).

2. Match the terms to the correct definition.
    a. Discharge
    b. Aquifer
    c. Unconformity
    d. Crystalline
    e. Porosity
    f. Permeability

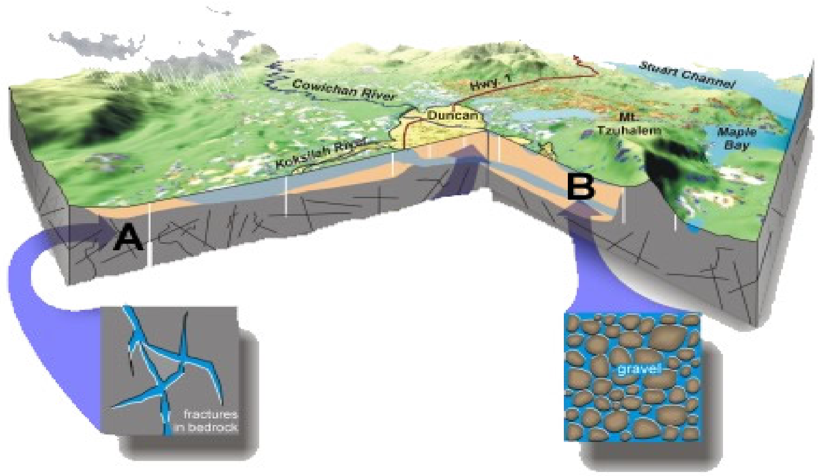
1. a permeable body of rock capable of yielding quantities of groundwater to wells or springs
2. the ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment
3. how well hydrocarbon fluids or water can flow through a porous formation or rock.
4. a rock made up of minerals in a clearly crystalline state; igneous or metamorphic rock as opposed to sedimentary rock
5. the relation between adjacent rock strata whose time of deposition was separated by a period of non-deposition or erosion; a break in the stratigraphic sequence

3. Imagine you work for a well drilling company. The well at site A water yields are excellent, ample water for municipal, commercial, irrigation, stock and domestic uses. What kind of water yields would you expect at site B?



a. No water yield at all.
b. The same water yield as site A
c. Potential water yield, if the rock is fractured and fractures are connected.
d. Lower water yield, but not as good at site A

4. Where do you expect water to flow easily (or easier) through the ground?

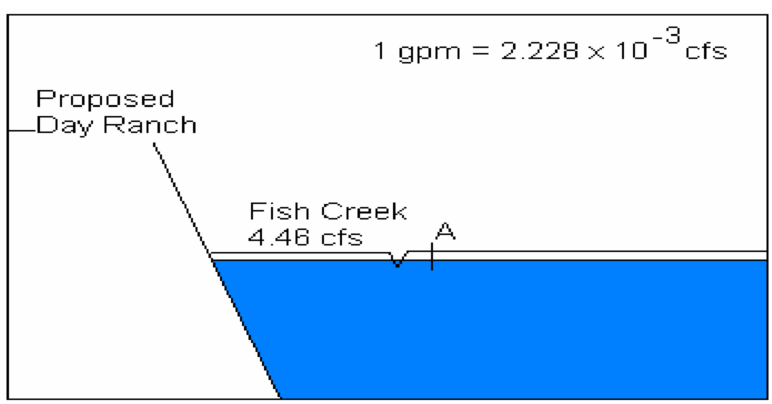


(Natural Resources Canada 2004)

a. A
b. B
c. A and B are the same
d. Neither A or B

5. Surface water and groundwater are connected (i.e. water flowing on the surface could have at one time been flowing underground).
a. True
b. False

6. If well A was pumping 226 gpm to a subdivision up on the bench (water is not likely to return to the valley), would you expect to see in decrease in flow in the Fish Creek? What would the post-pumping flow (in cfs) be?



a. 1775 cfs
b. 3.39 cfs
c. 2001 gpm
d. 0 cfs

SCORING RUBRIC FOR PRE-TEST DRAWING

Cartoon	
Schematic	
Concept Map	
Map view	

Aquifer?			
	Pool	1	
	saturated zone	2	
Rivers?			
	linked w/ground water	2	
	Separate	1	
Rock Type			
	porous		
	holds water	2	
	prevents water	1	
	crystalline		
	holds water	1	
	stops water	2	
	none indicated	0	

Groundwater	infiltrates	2	
	precipitation input		
	contribute	2	
	no connection	1	
	rivers		
	contribute	2	
	no connection	1	
	recharge area	2	
	discharge area	2	
Overall	excellent	4	
	good	3	
	acceptable	2	
	poor	1	
	none	0	

Total /22

POST-VIRTAL FIELD TRIP LOG

Please use the following confidence log to evaluate the virtual field trip. Read each statement and mark your appropriate confidence level. Please assess each statement fully and to the best of your ability. This is an ASSESSMENT not an EVALUATION. You must complete the confidence log, however your response to each statement will NOT affect your Geology 102 grade. ***Do NOT put your name on the sheet; include ONLY code name and group letter.***

Confidence Log/ Attitude Survey (Virtual Field Trip)

Topic	**Very confident**	**Confident**	**Some confidence**	**Little confidence**	**No confidence whatsoever**	**Not yet covered**
I can explain in detail where I went and where I was at all times.						
I can clearly define the term aquifer.						
I can describe the difference between the Archean gneiss and Tertiary sediments.						
I can explain why some rock units can store and transport more water than others.						
I can generally explain how and when the rock units I saw on the field trip were deposited						
I can explain how geology effects the location of water in the Gallatin Valley.						
I can explain the connection between the geology of the Gallatin Valley and the Day Ranch issue.						
I can formulate an argument for or against the Day Ranch.						
I feel like I can ask important questions regarding the Day Ranch issue.						
I can evaluate the validity of the data used in the Day Ranch argument.						
I can visualize what is underneath me without seeing it directly.						

Circle the most appropriate response:
1:strongly agree; 2:agree; 3:indifferent; 4: disagree; 5:strongly disagree; NA: not applicable

A. I enjoyed the virtual field trip.
1 2 3 4 5 NA

B. I developed and understanding of the area and issue.
1 2 3 4 5 NA

C. I understand the issue such that, I can write my final report, with all the necessary information.
1 2 3 4 5 NA

Comments:

ONE THE BACK OF THIS PAGE, PLEASE INCLUDE A CONCEPT MAP DESCRIBING YOUR UNDERSTANDING OF THE FIELD TRIP CONCEPT.

POST TRADITIONAL TRIP LOG

Please use the following confidence log to evaluate the virtual field trip. Read each statement and mark your appropriate confidence level. Please assess each statement fully and to the best of your ability. This is an ASSESSMENT not an EVALUATION. You must complete the confidence log, however your response to each statement will NOT affect your Geology 102 grade. ***Do NOT put your name on the sheet; include ONLY code name and group letter.***

Confidence Log/Attitude Survey (Traditional Field Trip)

Topic	**Very confident**	**Confident**	**Some confidence**	**Little confidence**	**No confidence whatsoever**	**Not yet covered**
I can explain in detail where I went and where I was at all times.						
I can clearly define the term aquifer.						
I can describe the difference between the Archean gneiss and Tertiary sediments.						
I can explain why some rock units can store and transport more water than others.						
I can generally explain how and when the rock units I saw on the field trip were deposited						
I can explain how geology effects the location of water in the Gallatin Valley.						
I can explain the connection between the geology of the Gallatin Valley and the Day Ranch issue.						
I can formulate an argument for or against the Day Ranch.						
I feel like I can ask important questions regarding the Day Ranch issue.						
I can evaluate the validity of the data used in the Day Ranch argument.						
I can visualize what is underneath me without seeing it directly.						

Circle the most appropriate response:
1:strongly agree; 2:agree; 3:indifferent; 4: disagree; 5:strongly disagree; NA: not applicable

A. I enjoyed the virtual field trip.
1 2 3 4 5 NA

B. I developed and understanding of the area and issue.
1 2 3 4 5 NA

C. I understand the issue such that, I can write my final report, with all the necessary information.
1 2 3 4 5 NA

Comments:

ONE THE BACK OF THIS PAGE, PLEASE INCLUDE A CONCEPT MAP DESCRIBING YOUR UNDERSTANDING OF THE FIELD TRIP CONCEPT.

FIELD NOTEBOOK SCORING RUBRIC

	Exemplary	**Quality**	**Adequate**	**Needs Improvement**	**No Answer**
Neatness	Neat, legible, clearly states stop location, date and time **10**	Neat, legible, missing some location information **8**	Readable, missing location information **6**	Hard to read, difficult to distingiush stop location etc. **4**	**0**
Sketches	Scales, clear observational skills, notes all necessary information. **10**	Neat, 1-2 errors **8**	Somewhat neat, less information in sketch, some scale information missing, 2+ errors **6**	Hard to read, no scale, poor quality, missing sketches **4**	**0**
Completeness	Addresses all the questions in field guide correctly. **10**	Addressess all the questions, 1-2 errors **8**	Missing 1-2 questions or 2+ errors **6**	Does not address questions, too many errors **4**	**0**
Terminology	Notes terms with definitions **10**	Terms, some missing, well defined **8**	Some terms, miss-defined **6**	Little to no terminology, inadequate descriptions **4**	**0**
Knowledge	Clear understanding of geology/purpose at each stop. Attentive to details and attentiveness to surroundings. **10**	Understands geology/purpose of stop. Less thorough, but complete **8**	Understands some geology/purpose. Missing components of stop information. **6**	Little to no understanding of geology/purpose. Clearly not paying attention at stops. **4**	**0**
				Total	

WRITE-UP REPORT SCORING RUBRIC

	Exemplary	Quality	Adequate	Needs Improvement	No Answer
Content	- Fully address the question - Includes all required information -Includes additional interesting/relevant information **10**	-Addresses question but needs more detail -Includes only required information **8**	- Address the question but somewhat tangentially -Includes most required information **6**	-Does not fully address question -Does not include required information (missing 2 or more) **4**	**0**
Application of Content	- Clearly states argument **5**	-States argument **4**	-States argument but not a clearly stated position **3**	-States no clear argument -Position is not defined **2**	**0**
Relevance of content knowledge	-Uses relevant data/information to support argument **5**	-Uses relevant data/information to support argument in less detail **4**	Uses minimal data to support argument **3**	- Uses no data to support argument **2**	**0**
Insight	- Identifies other data that might be useful in supporting argument - Provides possible solutions -Clearly understands geology **10**	-Identifies little extra data that could be used to support argument -mostly understands geology **8**	-Identifies irrelevant additional data to support argument -misunderstands geology **6**	Identifies no additional to support position - No geologic understanding - No additional insight **4**	**0**
Mechanics	- Proper use of style and grammar throughout report. **10**	-Proper use of grammar, some style issues (1-2 errors) **8**	-Some noticeable grammatical and style errors **6**	-Poor use of grammar and style -Extensive revision needed **4**	**0**
					TOTAL

CONCEPT MAP SCORING RUBRIC

	Exemplary	Quality	Adequate	Needs Improvement
Number of Concepts	Explains all the concepts on field trip; geology, policy and hydrology 10	Explains all of the concepts, is missing details 8	Explains most of the concepts is missing some details 6	Explains only some of the concepts and needs much more detail. 4
Validity of Linkages	Linkages between all concepts. Clearly understands the scope of problem 10	Linkages between concepts. Some missing links but all correct 8	Linkages between some concepts, some incorrect linkages 6	Linkages between few concepts, not clear understanding of linking between ideas 4
Terminology	Chart displays understanding of terms used. 10	Chart displays some understanding of terms used. 8	Some undefined or missing terminology 6	Misunderstanding of terms used. 4

POST-FIELD TRIP ATTITUDE QUESTIONAIRE

This questionnaire will serve as a reflection on your field trip experience. Your answers to the following questions will NOT affect your final grade in Geology 102. Answer the questions, in detail, on a separate sheet of paper (preferably typed) and turn them in by Thursday April, 29th. ***Do NOT put your name on the sheet; include ONLY code name and group letter.*** *Please answer questions honestly and constructively.*

1. Describe the value of the field trip experience.
    a. Did you enjoy the virtual field trip?
    b. Did you enjoy the traditional field trip?

2. Do you feel you established a good understanding of the topic and concepts during the virtual field trip?

3. How do you think your understanding of the topic and concepts changed after completing both the virtual and traditional field trip?

4. Do you think the virtual field trip was comparable to the traditional trip?

5. What skills did you develop on the virtual field trip?

6. What skills did you develop on the traditional field trip?

7. What would you change about the virtual field trip?

8. Do you see the possibility of virtual field trips replacing traditional field trip in the future?

9. Do you have any additional comments you would like to share about the field trip experience?

APPENDIX C:

DATA TABLES AND STATISTICS

I. Population Demographics

M	27	48%	Computer Y	53	95%		
F	29	52%	Computer N	3	5%		
Total	**56**	100%	Field Trip Y	14	25%		
Fresh	24	43%	Field Trip N	42	75%		
Soph	21	38%	VFT?	2	4%		
Junior	8	14%	Geosci Y	27	Took Geology @ MSU?	12 students	
Senior	3	5%	Geosci N	29			
Other	0	0%	**Total**	**56**			
Total	**56**	100%					

II. Class Pre-Test Data.

Group	Lab Session	Multiple Choice	%	Drawing	%	*Mean Score*
A	2	8	80%	18.5	84%	*82%*
	2	3	30%	0	0%	*15%*
	2	4	40%	5.5	25%	*33%*
	2	7	70%	9	41%	*55%*
	2	8	80%		0%	*40%*
	2	8	80%	10	45%	*63%*
	2	9	90%	12	55%	*72%*
	2	0.0	0%	0	0%	*0%*
	2	9	90%	12	55%	*72%*
	2	9	90%	12	55%	*72%*
	2	8	80%	11	50%	*65%*
	2	8	80%	9	41%	*60%*
	2	7	70%	7	32%	*51%*
	2	7	70%	0	0%	*35%*
	2	8	80%	5	23%	*51%*
	2	6	60%	7	32%	*46%*
	2	9	90%	13	59%	*75%*
	2	7	70%	3	14%	*42%*
	2	10	100%	4	18%	*59%*
	2	9	90%	15	68%	*79%*
	3	3	30%	4	18%	*24%*
	3	9	90%	5	23%	*56%*
	3	7.5	75%	15	68%	*72%*
	3	5	50%	4	18%	*34%*
	3	0	0%	0	0%	*0%*
	3	10	100%	1	5%	*52%*
	3	9	90%	15	68%	*79%*
	3	7	70%	3	14%	*42%*
	3	7	70%	2	9%	*40%*
	3	10	100%	14	64%	*82%*
	3	10	100%	3	14%	*57%*
	3	8	80%	5	23%	*51%*
	3	9	90%	9.5	43%	*67%*
	3	10	100%	5	23%	*61%*
	3	8	80%	9	41%	*60%*
	3	7	70%	7	32%	*51%*
	3	8	80%	10	45%	*63%*
	3	3.0	30%	10	45%	*38%*
	3	6	60%	9	41%	*50%*
	3	8	80%	10	45%	*63%*
B	4	6	60%	3	14%	*37%*
	4	7	70%	5	23%	*46%*
	4	7	70%	12	55%	*62%*
	4	9	90%	19	86%	*88%*

4	10	100%	6	27%	*64%*
4	6	60%	1	5%	*32%*
4	5	50%	14	64%	*57%*
4	9	90%	5	23%	*56%*
4	6	60%	11	50%	*55%*
4	5	50%	13	59%	*55%*
4	8.0	80%	5.5	25%	*53%*
4	8.0	80%	5	23%	*51%*
4	3.0	30%	2	9%	*20%*
4	9	90%	1	5%	*47%*
4	6.5	65%	6.5	30%	*47%*
4	9.0	90%	14	64%	*77%*
4	7	70%	4	18%	*44%*
4	4	40%	0	0%	*20%*

II. Confidence results, traditional field trip (n=15)

Topic	Very confident	Confident	Some confidence	Little confidence	No confidence whatsoever	Not yet covered
I can explain in detail where I went and where I was at all times.	5	5	5	0	0	0
Percentage	33%	33%	33%	0%	0%	0%
I can clearly define the term aquifer.	3	4	7	1	0	0
Percentage	20%	27%	47%	7%	0%	0%
I can describe the difference between the Archean gneiss and Tertiary sediments.	5	8	2	0	0	0
Percentage	33%	53%	13%	0%	0%	0%
I can explain why some rock units can store and transport more water than others.	8	6	1	0	0	0
Percentage	53%	40%	7%	0%	0%	0%
I can generally explain how and when the rock units I saw on the field trip were deposited	3	7	3	2	0	0
Percentage	20%	47%	20%	13%	0%	0%
I can explain how geology effects the location of water in the Gallatin Valley.	4	7	4	0	0	0
Percentage	27%	47%	27%	0%	0%	0%
I can explain the connection between the geology of the Gallatin Valley and the Day Ranch issue.	3	8	4	0	0	0
Percentage	20%	53%	27%	0%	0%	0%
I can formulate an argument for or against the Day Ranch.	5	8	2	0	0	0
Percentage	33%	53%	13%	0%	0%	0%

I feel like I can ask important questions regarding the Day Ranch issue.	4	7	4	0	0	0
Percentage	27%	47%	27%	0%	0%	0%
I can evaluate the validity of the data used in the Day Ranch argument.	4	6	5	0	0	0
Percentage	27%	40%	33%	0%	0%	0%
I can visualize what is underneath me without seeing it directly.	4	4	6	1	0	0
Percentage	27%	27%	40%	7%	0%	0%
Class Total	***48***	***70***	***43***	***4***	***0***	***0***
Percentage	***29.1%***	***42.4%***	***26.1%***	***2.4%***	***0.0%***	***0.0%***

III. Confidence results, virtual field trip (n=38)

Topic	**Very confident**	**Confident**	**Some confidence**	**Little confidence**	**No confidence whatsoever**	**Not yet covered**
I can explain in detail where I went and where I was at all times.	3	15	17	3	0	0
Percentage	7.9%	39.5%	44.7%	7.9%	0.0%	0.0%
I can clearly define the term aquifer.	7	15	9	7	0	0
Percentage	18.4%	39.5%	23.7%	18.4%	0.0%	0.0%
I can describe the difference between the Archean gneiss and Tertiary sediments.	5	11	11	10	1	0
Percentage	13.2%	28.9%	28.9%	26.3%	2.6%	0.0%
I can explain why some rock units can store and transport more water than others.	16	17	3	2	0	0
Percentage	42.1%	44.7%	7.9%	5.3%	0.0%	0.0%
I can generally explain how and when the rock units I saw on the field trip were deposited	2	7	18	10	1	0
Percentage	5.3%	18.4%	47.4%	26.3%	2.6%	0.0%
I can explain how geology effects the location of water in the Gallatin Valley.	4	17	13	2	1	0
Percentage	10.5%	44.7%	34.2%	5.3%	2.6%	0.0%
I can explain the connection between the geology of the Gallatin Valley and the Day Ranch issue.	2	17	11	7	1	0
Percentage	5.3%	44.7%	28.9%	18.4%	2.6%	0.0%

I can formulate an argument for or against the Day Ranch.	2	17	14	4	1	0
Percentage	5.3%	44.7%	36.8%	10.5%	2.6%	0.0%
I feel like I can ask important questions regarding the Day Ranch issue.	3	19	10	6	0	0
Percentage	7.9%	50.0%	26.3%	15.8%	0.0%	0.0%
I can evaluate the validity of the data used in the Day Ranch argument.	3	11	15	9	0	0
Percentage	7.9%	28.9%	39.5%	23.7%	0.0%	0.0%
I can visualize what is underneath me without seeing it directly.	3	11	14	7	3	0
Percentage	7.9%	28.9%	36.8%	18.4%	7.9%	0.0%
Class Total	***48.0***	***150.0***	***117.0***	***57.0***	***7.0***	***0.0***
Percentage	***12.7%***	***39.6%***	***30.9%***	***15.0%***	***1.8%***	***0.0%***

IV. Understanding and enjoyment results, virtual (n =38) and traditional (n=15)

Topic	**1 (strongly agree)**	**2 (agree)**	**3 (indifferent)**	**4 (disagree)**	**5 (strongly disagree)**
I enjoyed the virtual field trip. (Virtual)	0	13	18	0	3
Percentage	0%	38%	53%	0%	9%
I developed an understanding of the area and issue. (Virtual)	4	25	3	2	0
Percentage	12%	74%	9%	6%	0%
I developed an understanding of the area and issue. (Traditional)	7	8	1	0	0
Percentage	44%	50%	6%	0%	0%
I understand the issue such that I can write my final report with all the necessary information. (Virtual)	0	11	15	8	0
Percentage	0%	32%	44%	24%	0%
I understand the issue such that I can write my final report with all the necessary information. (Traditional)	4	9	3	0	0
Percentage	25%	56%	19%	0%	0%

V. Concept Map results

	VFT Only			**VFT + TRAD (A)**		
	# of concepts	validity of linkages	terminology	# of concepts	validity of linkages	terminology
	6	3	3	4	5	3
	4	0	2	6	0	3
	4	2	1	4	5	5
	3	5	5	5	6	7
	4	0	7	4	0	1
	1	1	0	4	4	3
	3	0	1	6	6	5
	4	0	0	1	0	0
	3	1	7	5	4	4
	2	0	5	2	0	1
	3	2	0	0	0	0
	3	0	2	2	1	4
	4	2	1	3	0	3
	3	0	0	3	0	6
	5	0	0	2	1	0
	1	0	0	3	0	0
	4	3	1	5	4	1
	2	1	0	3	5	0
	4	0	2	3	2	0
	2	0	4	2	0	0
	2	0	3	4	0	0
	2	1	1	3	0	0
	1	0	0	3	1	1
	2	0	1	4	0	4
	3	2	1	5	0	3
	3	3	1	4	5	3
	3	0	0	8	6	8
	5	4	1	6	0	8
	4	6	3	2	6	4
	3	2	5	7	0	0
	4	0	1	2	1	7
	3	0	1	2	1	0
	5	1	6	3	0	0
	5	0	6	3	0	5
	6	2	4	3	4	4
	6	0	1			
	3	0	0			
	3	0	0			
Mean	**3.4**	**1.1**	**2.0**	**3.6**	**1.9**	**2.7**
Median	**3**	**0**	**1**	**3**	**1**	**3**

TRAD			**TRAD + VFT (B)**		
# of concepts	validity of linkages	terminology	# of concepts	validity of linkages	terminology
3	0	0	3	0	5
5	0	2	3	1	5
3	0	0	2	0	0
5	0	3	2	0	3
3	0	0	1	0	0
5	0	3	3	0	5
3	0	0	4	0	4
6	2	4	2	0	0
3	0	0	2	1	1
5	2	1	3	4	0
8	3	1	2	3	5

	3	0	0	2	1	0
	5	0	0	2	0	0
	4	0	0	2	0	3
	5	0	5	1	0	0
	1	3	0	2	0	0
	1	3	0			
Mean	**4**	**1**	**1**	**2**	**1**	**2**
Median	**4**	**0**	**0**	**2**	**0**	**1**

VI. Notebook Results, virtual and traditional

Field Trip	Stop 5	Hypotheses	Sketches	Note Detail	Completeness	Total
A-Virtual	6	8	6	6	6	32
A-Virtual	5	4	4	4	6	23
A-Virtual	4	4	4	4	6	22
A-Virtual	6	6	6	6	8	32
A-Virtual	4	2	6	5	6	23
A-Virtual	8	8	6	6	7	35
A-Virtual	9	6	4	5	6	30
A-Virtual	4	4	3	5	5	21
A-Virtual	9	4	6	6	6	31
A-Virtual	8	8	9	6	8	39
A-Virtual	4	6	6	6	6	28
A-Virtual	5	8	7	7	8	35
A-Virtual	6	8	6	5	6	31
A-Virtual	5	3	6	6	7	27
A-Virtual	6	8	6	5	6	31
A-Virtual	0	8	6	6	6	26
A-Virtual	4	0	6	5	6	21
A-Virtual	7	3	8	7	7	32
A-Virtual	7	8	5	6	8	34
A-Virtual	3	5	4	4	5	21
A-Virtual	8	8	5	7	7	35
A-Virtual	8	0	6	6	8	28
A-Virtual	6	8	6	6	5	31
A-Virtual	4	8	4	6	6	28
A-Virtual	9	8	6	6	6	35
A-Virtual	6	8	6	6	6	32
A-Virtual	6	8	7	6	6	33
A-Virtual	6	8	7	7	6	34
A-Virtual	4	8	8	8	8	36
A-Virtual	6	5	4	6	6	27
A-Virtual	7	8	6	6	7	34
A-Virtual	4	4	6	5	6	25
A-Virtual	8	9	4	7	7	35
A-Virtual	6	0	5	5	4	20
A-Virtual	5	0	4	6	4	19
A-Virtual	0	8	4	6	4	22
A-Virtual	6	0	6	7	6	25
A Mean	***5.6***	***5.6***	***5.6***	***5.8***	***6.2***	***29***
A Median	***6.0***	***8.0***	***6.0***	***6.0***	***6.0***	***31***
St. Dev.	***2.1***	***2.3***	***1.32***	***0.9***	***1.1***	***5***
B-Virtual	6	8	5	9	10	38
B-Virtual	8	8	6	8	9	39
B-Virtual	4	8	5	6	6	29

B-Virtual	6	8	4	5	5	28
B-Virtual	7	8	6	6	8	35
B-Virtual	6	8	6	6	6	32
B-Virtual	6	9	7	5	6	33
B-Virtual	0	8	6	6	6	26
B-Virtual	6	9	6	6	5	32
B-Virtual	9	8	5	8	7	37
B-Virtual	8	10	5	7	8	38
B-Virtual	7	10	7	8	8	40
B-Virtual	7	8	5	5	6	31
B-Virtual	4	6	5	6	6	27
B Mean	***6.0***	***8.3***	***5.6***	***6.5***	***6.9***	***33***
B Median	***6.0***	***8.0***	***5.5***	***6.0***	***6.0***	***33***
St. Dev.	***2.2***	***1***	***0.85***	***1.3***	***1.5***	***5***
Class Mean	**5.9**	**6.5**	**5.7**	**6.1**	**6.5**	**32.10**
A-Traditional	6	7	6	6	8	33
A-Traditional	0	4	0	4	6	14
A-Traditional	8	0	4	6	6	24
A-Traditional	5	0	6	6	8	25
A-Traditional	0	0	6	4	4	14
A-Traditional	8	4	8	6	8	34
A-Traditional	9	9	7	8	8	41
A-Traditional	6	8	6	7	8	35
A-Traditional	0	0	6	6	4	16
A-Traditional	0	8	9	8	8	33
A-Traditional	0	10	7	6	8	31
A-Traditional	6	8	8	7	9	38
A-Traditional	0	6	4	4	6	20
A-Traditional	0	9	9	6	8	32
A-Traditional	7	8	6	6	8	35
A-Traditional	6	8	9	6	8	37
A-Traditional	0	0	7	4	4	15
A-Traditional	8	6	7	6	8	35
A-Traditional	4	8	6	6	8	32
A-Traditional	6	8	6	6	8	34
A-Traditional	5	7	5	6	6	29
A-Traditional	9	8	10	9	8	44
A-Traditional	6	8	6	9	8	37
A-Traditional	0	3	4	8	4	19
A-Traditional	0	0	5	6	4	15
A-Traditional	9	8	6	6	8	37
A-Traditional	0	8	6	7	4	25
A-Traditional	4	4	6	6	6	26
A-Traditional	6	9	6	7	8	36
A-Traditional	0	0	8	6	4	18
A-Traditional	0	0	8	8	4	20
A-Traditional	8	8	5	6	8	35
A-Traditional	4	7	5	6	6	28
A-Traditional	8	8	9	6	7	38
A-Traditional	4	8	4	6	4	26
A-Traditional	0	8	5	10	9	32
A-Traditional	4	9	9	9	9	40
A Ave	***3.9***	***5.8***	***6.3***	***6.5***	***6.8***	***29***

A Median	***4.0***	***8.0***	***6.0***	***6.0***	***8.0***	***32***
STDEV	***3.41***	***3.42***	***1.93***	***1.41***	***1.79***	***9***
B-Traditional	0	8	7	7	8	30
B-Traditional	6	8	9	9	8	40
B-Traditional	4	0	7	5	4	20
B-Traditional	4	7	4	6	5	26
B-Traditional	7	8	9	8	8	40
B-Traditional	6	6	6	6	8	32
B-Traditional	8	8	6	9	8	39
B-Traditional	8	4	6	6	8	32
B-Traditional	6	4	7	7	8	32
B-Traditional	6	9	8	6	8	37
B-Traditional	4	8	7	7	8	34
B-Traditional	0	8	9	10	5	32
B-Traditional	6	8	6	6	6	32
B-Traditional	6	8	5	9	6	34
B MEAN	***5.1***	***6.7***	***6.9***	***7.2***	***7.0***	***33***
B Median	***6.0***	***8.0***	***7.0***	***7.0***	***8.0***	***32***
STDEV	***2.5***	***2.5***	***1.5***	***1.53***	***1.47***	***5.4***
Class Av.	**4.3**	**6.2**	**6.6**	**6.8**	**7**	**32.3**

VII. Students willing to use data and number interested in gathering more data prior to committing to argument.

Traditional		Virtual	
Use Data	# of students	Use Data	# of students
Y (A)	14	Y (A)	31
N (A)	1	N (A)	4
No answer (A)	22	No answer (A)	2
Y (B)	2	Y(B)	11
N (B)	3	N(B)	0
No answer (B)	9	No answer (B)	3
Total	**51**	**Total**	**51**
More Data	# of students	More Data	# of students
Y (A)	9	Y(A)	22
N (A)	6	N (A)	12
No answer (A)	22	No answer (A)	3
Y (B)	5	Y (B)	10
Y (B)	2	N (B)	3
No answer (B)	7	No answer (B)	1
Total	**51**	**Total**	**51**
Use Data Y	Use Data N	Use Data Y	Use Data N
16	4	42	4
31.4%	7.8%	82.4%	7.8%
More Y	More N	More Y	More N
14	8	32	15
27.5%	15.7%	62.7%	29.4%

VIII. Final Report Results, virtual and traditional field trip.

Group	FT Rep.	%		Group	FT Rep.	%
A	27.5	68.8%		B	25.5	63.8%
A	19	47.5%		B	39	97.5%
A	22.5	56.3%		B	28	70.0%
A	24.5	61.3%		B	30.5	76.3%
A	26.5	66.3%		B	20	50.0%
A	8	20.0%		B	20.5	51.3%
A	20.5	51.3%		B	33.5	83.8%
A	23.5	58.8%		B	24	60.0%
A	25	62.5%		B	14.5	36.3%
A	31	77.5%		B	17	42.5%
A	35	87.5%		B	12	30.0%
A	22.5	56.3%		B	27.5	68.8%
A	14	35.0%		B	30.5	76.3%
A	10	25.0%		B	23.5	58.8%
A	21.5	53.8%		B	32	80.0%
A	24.5	61.3%		B	24	60.0%
A	12	30.0%		**B Mean**	***25.1***	***62.8%***
A	32	80.0%		**B Median**	***24.8***	***61.9%***
A	28	70.0%		**StDEV**	***7.2***	***18.1%***
A	31	77.5%		**Class Ave**	**25.3**	**63%**
A	31	77.5%				
A	17	42.5%				
A	30.5	76.3%				
A	32	80.0%				
A	31.5	78.8%				
A	17.5	43.8%				
A	26	65.0%				
A	22	55.0%				
A	33.5	83.8%				
A	26.5	66.3%				
A	34	85.0%				
A	33	82.5%				
A	31	77.5%				
A	29	72.5%				
A	32	80.0%				
A	20	50.0%				
A	30	75.0%				
A	29.5	73.8%				
A Mean	***25.4***	***63.5%***				
A Median	***26.5***	***66.3%***				
StDEV	***6.97***	***17.43%***				

<u>STATISTICS</u>

IX. Descriptive Statistics for Notebook results:

	Stop 5	Hypotheses	Sketches	Note Detail	Completeness	Total
	A VFT	**A VFT**	**A VFT**	**A VFT**	**A VFT**	**A VFT**
Mean	5.65	5.65	5.62	5.84	6.24	29
SD	2.12	2.95	1.32	0.9	1.09	5.45
SEM	0.35	0.48	0.22	0.15	0.18	0.9
N	37	37	37	37	37	37
90% CI	5.06 to 6.24	4.83 to 6.47	5.26 to 5.99	5.59 to 6.09	5.94 to 6.55	27.49 to 30.51
95% CI	4.94 to 6.36	4.67 to 6.63	5.18 to 6.06	5.54 to 6.14	5.88 to 6.61	27.18 to 30.82
99% CI	4.70 to 6.60	4.33 to 6.97	5.03 to 6.21	5.44 to 6.24	5.76 to 6.73	26.56 to 31.44
Minimum	0	0	3	4	4	19
Median	6	8	6	6	6	31
Maximum	9	9	9	8	8	39
	B VFT	**B VFT**	**B VFT**	**B VFT**	**B VFT**	**B VFT**
Mean	6	8.29	5.57	6.5	6.86	33.21
SD	2.22	0.99	0.85	1.29	1.51	4.69
SEM	0.59	0.27	0.23	0.34	0.4	1.25
N	14	14	14	14	14	14
90% CI	4.95 to 7.05	7.82 to 8.76	5.17 to 5.97	5.89 to 7.11	6.14 to 7.57	30.99 to 35.44
95% CI	4.72 to 7.28	7.71 to 8.86	5.08 to 6.06	5.76 to 7.24	5.98 to 7.73	30.50 to 35.92
99% CI	4.21 to 7.79	7.49 to 9.09	4.89 to 6.26	5.46 to 7.54	5.64 to 8.07	29.44 to 36.99
Minimum	0	6	4	5	5	26
Median	6	8	5.5	6	6	32.5
Maximum	9	10	7	9	10	40
	A TFT	**A TFT**	**A TFT**	**A TFT**	**A TFT**	**A TFT**
Mean	3.95	5.78	6.32	6.46	6.76	29.27
SD	3.41	3.42	1.93	1.41	1.79	8.53
SEM	0.56	0.56	0.32	0.23	0.29	1.4
N	37	37	37	37	37	37
90% CI	3.00 to 4.89	4.83 to 6.73	5.79 to 6.86	6.07 to 6.85	6.26 to 7.25	26.90 to 31.64
95% CI	2.81 to 5.08	4.64 to 6.93	5.68 to 6.97	5.99 to 6.93	6.16 to 7.35	26.43 to

						32.11
99% CI	2.42 to 5.47	4.25 to 7.31	5.46 to 7.19	5.83 to 7.09	5.96 to 7.56	25.46 to 33.08
Minimum	0	0	0	4	4	14
Median	4	8	6	6	8	32
Maximum	9	10	10	10	9	44

	B TFT	**B TFT**	**B TFT**	**B TFT**	**B TFT**	**B TFT**
	5.07	6.71	6.86	7.21	7	32.86
SD	2.5	2.46	1.51	1.53	1.47	5.43
SEM	0.67	0.66	0.4	0.41	0.39	1.45
N	14	14	14	14	14	14
90% CI	3.89 to 6.25	5.55 to 7.88	6.14 to 7.57	6.49 to 7.94	6.31 to 7.69	30.29 to 35.43
95% CI	3.63 to 6.51	5.29 to 8.14	5.98 to 7.73	6.33 to 8.10	6.15 to 7.85	29.72 to 35.99
99% CI	3.06 to 7.08	4.73 to 8.70	5.64 to 8.07	5.98 to 8.44	5.82 to 8.18	28.48 to 37.23
Minimum	0	0	4	5	4	20
Median	6	8	7	7	8	32
Maximum	8	9	9	10	8	40

X. T-test results and significance.

Assessment	**Two Tail p-value**	**Confidence Interval (%)**	**Statistically Significant?**	**t**	**degrees of freedom**	**standard error of difference**
Write up: group A vs. group B scores	0.2681	95%	No	1.150	15	0.067
Write up: pre-test vs. write up scores	0.0013	95%	Yes	3.415	51	0.030
Concept Map: number of concepts, group A	0.4313	95%	No	0.796	34	0.359
Concept Map: validity of linkages, group A	0.0457	95%	Yes	2.074	34	0.358
Concept Map: terminology, group A	0.3829	95%	No	0.884	34	0.582
Concept Map: number of concepts, group B	0.0008	95%	Yes	4.206	15	0.461
Concept Map: validity of linkages, group B	1.0000	95%	No	0.000	15	0.289
Concept Map: terminology, group B	0.2916	95%	No	1.093	15	0.686

Concept Map: number of concepts, group A vs. group B	0.0107	95%	Yes	2.915	15	0.386
Concept Map: validity of linkages, group A vs. group B	0.0959	95%	No	1.777	15	0.774
Concept Map: terminology, group A vs. group B	0.2192	95%	No	1.282	15	0.682
Notebook: stop 5, virtual vs. traditional	0.0067	95%	Yes	2.768	100	0.538
Notebook: sketches, virtual vs. traditional	0.0058	95%	Yes	2.819	100	0.306
Notebook: hypotheses, virtual vs. traditional	0.5772	95%	No	0.559	100	0.596
Notebook: note detail, virtual vs. traditional	0.0118	95%	Yes	2.5647	100	0.252
Notebook: completeness, virtual vs. traditional	0.1638	95%	No	1.4026	100	0.294