Visualizing Historic Space through the Integration of Geographic Information Science in Secondary School Curriculums:

A Comparison of Static versus Dynamic Methods

by

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To my wife, April, and daughters, Lorraine and Natasha; thank you for all of your love and support (and patience).

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List of Abbreviations

DSA	Data Sharing Agreement
GIS	Geographic information system
HIDOE	Hawaii Department of Education
IRB	Institutional Review Board
PBL	Problem Based Learning
SSI	Spatial Sciences Institute
USC	University of Southern California

Abstract

Spatial scientists spent the better part of the last three decades pushing for further integration of Geographic Information Science (GIS) technologies in K – 12 curriculums. Their efforts to date are leading to moderate breakthroughs in geography and physical sciences, but social studies continue to neglect its use almost entirely. Unfortunately, little empirical evidence exists that suggests students realize quantifiable gains from its inclusion in the classroom. In fact, the findings from most research comparing visualization methods indicate that static mapping methods outperform dynamic methods when assessed by the user's ability to extract information from the product. This study adds to existing literature by expanding upon current research into static versus dynamic visualization methods. In contrast to previous visualization studies that focus heavily on animation for their dynamic representations, this study tested static methods against story maps to determine whether they provide teachers an advantage in the classroom.

To develop its findings, the study employed standard classroom instruction methods and examination materials to identify which visualization method most effectively communicated the material to students in secondary school history classrooms. The study divided students into a control group using standard classroom static visualization tools, and an experimental group using dynamic story maps. Written exams conducted immediately following initial instruction, and again two weeks later, provided the basis for evaluation. The study failed to demonstrate that dynamic products provide students a distinct advantage over traditional static products in a classroom environment. Its findings suggest that students can use both tools equally effectively, supporting the findings from previous research. Of note, this study suggests that among female students, dynamic products may yield decreased learning outcomes. This indicates the need for further research to identify how gender affects visualization strategies.

Chapter 1 : Introduction

Secondary school social studies teachers rely on cartographic tools to relay complex spatial-temporal concepts to their students. In Hawaii, state standards require students to develop spatial skills to analyze and interpret data from maps relating to people, places, and environments so that they can explain the interactions between geographic regions, and various societies throughout history (Hawaii Standards 2005). However, as Mares and Moschek argue, to fully appreciate the relationship between humans and geographic space, students must recognize and contend with the, “imaginative quality of their own views.” (Mares and Moschek 2013) In other words, teachers and students must recognize and account for the ways that their personal prejudices influence the manner in which they interpret spatial-temporal data.

This study seeks to determine how students interpret data through cartographic visualization tools to determine if employing computer-based geographic information science (GIS) technology makes sense at the secondary level, in social studies classrooms. The findings are based on empirical comparisons of standard, static classroom visualization tools, and emerging dynamic story map applications hosted by Esri through ArcGIS online. In the context of this study, a story map is defined as a web based application that enables the author to fuse a live, web-based map, with narrative text, photographs, timelines, and other sources of digital media to enhance the delivery of information to the user. The study asks students to respond to a series of written questions following a fifteen minute instructional period on the Bascom Affair, using the specific visualization tool being implemented: static teaching aids or Esri story maps. Through this classroom performance experiment, the study intends to understand which tool sets yield more effective results in the classroom learning environment based on the students’ ability to extract and interpret data from the maps provided. This study hypothesized that story maps would provide a more effective means of relaying complex ideas, and that the increased student interaction with the materials would lead to improved long term memory retention and greater critical thinking skills.

1.1 Motivation

Pushing to integrate GIS into secondary school classrooms is not a new concept. However, despite professional development courses geared toward further GIS integration in secondary school curriculums, a significant gap exists between teachers trained to use GIS and those implementing the tools in their classrooms. The theory that teachers who are trained to use new methods will employ them to the benefit of their students has not borne fruit. In fact, according to Lisner, much of the professional development received by teachers to implement GIS in their classrooms has been wasted effort. In her dissertation at Northern Illinois, Lisner articulated three primary barriers to integration that prevent teachers from willingly transitioning to unproven methods: Learning to use the software requires too much time outside of the classroom; schools lack funding for the hardware and software requirements; and a lack of support from the administrative level. (Lisner 2008)

The limited gains that have been realized tend to center around integrating GIS into teaching geography and physical sciences. Over the last 15 years, historians began recognizing the relationship between history and geography, based on the way that humans perceive events in space and time. Unfortunately, despite acknowledging the relationship, secondary schools have made almost no progress when it comes to integrating GIS into history curriculums. (Knowles 2014) This may be influenced, in part, by the belief held by mainstream historians that GIS offers no credible gains to their field of study. (Lunen and Travis 2013)

Although certain specializations in history welcome GIS, the major organizations that dictate the direction of the professional field (Royal Historical Society, American Historical Association, and the Deutsche Historikertag) demonstrate no inclination toward its widespread adoption. Similar to the challenges faced at the secondary education level, historians perceive that GIS poses too great of an initial investment in time, training, and resources to justify its use. Much like the decision to abandon the use of quantitative analysis following its peak in the 1960s, the decision to ignore GIS reflects a conscious decision. Ultimately, professional historians do not believe that GIS will forward their knowledge by answering the essential questions in their discipline. (Lunen and Travis 2013)

Ironically, while this mentality creates a significant obstacle to integrating GIS in secondary curriculums, it also provides its greatest justification. Spatial perception skills are realized in most humans between the ages of 12 and 15 years. (Mares and Moschek 2013, 61) It stands then to reason that incorporating GIS into secondary curriculums will further develop these skills and reduce the initial investment required as adults to integrate spatial reasoning into historical study. Thanks to advances in modern technology, and the current generation's familiarity with web-based GIS applications and commercial global positioning system (GPS) software, modern secondary school students already possess the will and many of the basic skills required to leverage GIS in the classroom. (Lisner 2008, 7)

Lunen and Travis argue that it is more important to demonstrate why historians should embrace GIS by providing concrete examples of benefits that the field stands to gain. Likewise, from a curriculum development point of view, research must demonstrate that GIS technology can enhance current lesson plans (2013). Professional development and Spatial History theory will only advance the integration of GIS into secondary school history curriculums so far. For widespread implementation to occur, GIS use must result in a quantitative increase in student performance to justify the personal risk and accompanying costs that it carries.

Lisner identified that the body of teachers who are currently employing GIS in their classrooms, despite the barriers to implementation, do so because they understand that GIS increases their students' critical thinking and decision-making skills (2008). Unfortunately, current visualization literature fails to demonstrate that GIS will enhance student performance in social studies. Before widespread GIS integration in secondary schools can become a reality, additional visualization research is needed to demonstrate why dynamic visualization tools benefit students. This study represents an initial step toward providing that body of research.

1.2 Study Design

The study’s primary objective is to measure student performance in executing map based knowledge extraction tasks, and their ability to accurately interpret and analyze spatial-temporal relationships using cartographic visualization tools. The experiment design is influenced in part by the work of Ben Anderson. Anderson's 2015 thesis at the University of Southern California tested static maps against animated maps to determine the user's ability to extract criminal activity data. This study adopts Anderson’s metrics of effectiveness and efficiency to determine the overall benefit of each visualization method by recording the accuracy of student responses on a written exam, and overall time required for each student to complete testing.

In addition to Anderson’s research, Liu et al.’s Problem Based Learning (PBL) experiment influenced the research tool for this study. To assess critical thought and higher level learning objectives, Liu et al. used Bloom’s taxonomy of cognitive learning skills demonstrated in Figure 1 on page 5. (2010) Liu et al. determined that recall reflected the students’ ability to remember important facts, numbers, or events; understanding indicated the students' ability to explain figures, tables, and concepts clearly outlined or provided in the lesson material; analyze reflected consideration of cause and effect; evaluate judged that the student provided critical or expansive comments that go beyond recall; and create applied to genuine or creative ideas of interpretations or solutions to the questions that the student could not identify explicitly in the lesson material. (Lui et al. 2010) This study employed the taxonomy developed by Liu et al to produce the rubric used to define levels of critical thought in the research population.

This study does not propose to conclude the overarching superiority of either method of visualization. Its sole intent is to determine which method produces improved learning results in the classroom. In so doing, this study expands upon the broader body of visualization literature. Through the empirical comparison of student test scores, the study provides focus on the advantages and disadvantages of each form of visualization in a previously unstudied context. However, its findings should not be accepted as universal.

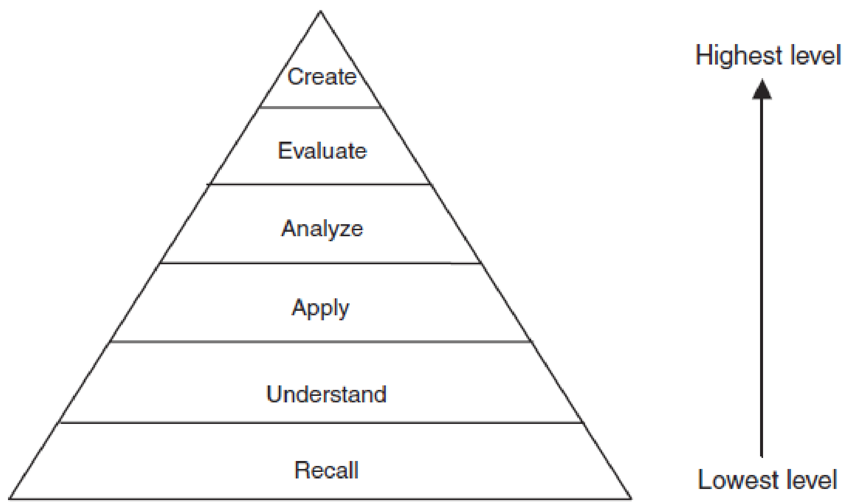

Figure 1 - Bloom's Taxonomy of Cognitive Learning Skills as revised by Krathwohl (2002) (Liu et al. 2010, 154)

1.3 Research Questions

To reinforce the scope of this research, this study focused primarily on secondary school level students' ability to extract data using standard static classroom visualization tools, or dynamic story maps hosted by Esri through ArcGIS online. This study was conducted to determine whether story maps offer teachers an advantage in the classroom over traditional static products by answering the following research questions:

1. Are there measurable increases in student performance in knowledge extraction?
2. Does the use of story maps increase the likelihood transitioning ideas from short term to long term memory?
3. Do story maps facilitate critical thought through active participation with data as it is presented?

The initial hypotheses reflect that story maps should provide a more effective means of relaying complex ideas than traditional static products due to the assumptions that:

1. Students would perform knowledge extraction tasks with greater effectiveness and efficiency with story maps.
2. Active engagement with the materials would increase the depth of processing that students afford to new concepts, resulting in increased transition of ideas from short term to long term memory.
3. Active engagement with the materials would generate classroom participation, leading to increased critical thought and higher level learning outcomes.

1.4 Study Organization

After introducing the study in this chapter, chapter 2 further defines the visualization methods compared in the study; identifies the present landscape of GIS in secondary school curriculums; reviews related work into visualization methods; and articulates opportunities for GIS integration in secondary school, social studies classrooms. Chapter 3 covers the research design and methods used for the study to include: The steps required to secure and protect the research population; lesson plan development; and the focus of data collected on the exam tool. It also covers a selection of appropriate lesson material for the study; GIS datasets utilized to develop the study tools; levels of data aggregation; a description of the visualization tools; and the methods employed to analyze the study's findings. Chapter 4 identifies the study's findings, broken down by each of the study's three research questions, and concludes with a discussion of qualitative findings produced during the classroom experiment. Chapter 5 provides discussion on the study's findings; an assessment of the study's relative strengths and weaknesses; recommendations for future research; and conclusions.

Chapter 2 : Related Work

As introduced in chapter 1, this study restricts its scope to comparing static and dynamic cartographic visualization techniques in a standard classroom environment. This chapter reviews the existing visualization literature that influenced the study design, and creation of the research tools employed. However, before going further, two critical terms must be defined for the reader: *Static* and *Dynamic.*

The study adheres to Mares and Moschek's definitions for static and dynamic mapping techniques. Static products imply conventional classroom tools employed in secondary school social studies instruction: printed maps, pictures, texts, and timelines. In line with Mares and Moschek, static maps are defined by the user's inability to manipulate the data portrayed. As such, students are forced to visualize the data as the cartographer envisioned. In contrast, dynamic maps enable the user to manipulate how the data are represented and choose how they wish to visualize the information provided. (Mares and Moschek 2013) Based on this understanding, this study departs from previous definitions used by Anderson (2015) and Baldwin (2014) in their research. Planimetric maps provide the user with the ability to manipulate how they view the data through layered analysis techniques. Therefore, while this study accepts the use of small multiple map displays as static products, it rejects planimetric tools. For the same reason, this study asserts that digital GIS technologies are inherently dynamic in nature because the user has the ability to control the data, and rapidly transform the information visualized.

2.1 The Present Landscape of GIS in Secondary School Curriculums

Most research focused on the challenges facing further GIS integration into secondary school curriculums leverage survey instruments as their main methodology for gathering their data. (Lisner 2008) Because of this, the studies have excellent continuity and support each other's findings well. However, with few exceptions, the vast majority have focused almost exclusively on reasons inhibiting further adoption. The research community has a very strong understanding of the roadblocks ahead as a result. Unfortunately, less is understood about opportunities for change or the potential benefits of GIS-enhanced curriculums

In 2013, Kerski, Demirci, and Milson, published their findings on the global landscape of GIS in secondary education in the Journal of Geography. Principal among their findings was the fact that despite claims otherwise, the technology gap remained a challenge to implementation. President Obama's 2014 ConnectEd initiative and Esri's gift of free ArcGIS online organizational accounts to K-12 teachers have largely settled issues related to hardware and software availability. Schools now receive federal funding for classroom computers and wireless internet services, and Esri's software and web portals alleviate the requirement for schools to manage their own spatial data repositories on site. However, software complexity remains a concern for further integration. Teachers still require training on GIS practices and software, and ongoing mentorship to effectively integrate the technology into their curriculums. (Richardson and Solem 2014) Both endeavors require them to commit significant effort and personal time.

Software complexity challenges students in the classroom as well. Although students approach learning through new technologies with high levels of excitement (often greater than educators), the complexity of GIS software can quickly squander their initial interest. (Artvinli 2010) Most commercial GIS applications are not designed with classroom curriculums in mind. The non-spatial workflows prove tedious to users over time and can inhibit visualization, suggesting the need for a simplified, gesture based, instructional tool. (Blaser, Sester, and Egenhofer 2000)

Most commercial and university outreach programs have focused on developing capacity from the bottom, up. (Demirci, Karaburun, and Ünlü 2013, and Kerski, Demirci, and Milson 2013) There are many opportunities geared at professional development for teachers that assist them with how to incorporate GIS into their lessons. However, educating teachers, and getting them to translate their training into classroom practices are separate challenges. Remember, based on her findings, Lisner called the GIS-based professional development that teachers receive a wasted effort. (Lisner 2008) Unfortunately, as schools moved toward national common core standards, opportunities for innovation in the classroom decreased and teachers became less likely to search for solutions to incorporate new technologies. Teachers are trained to teach students using proven methodologies to enhance student performance. (Chalmers 2010) GIS remains unproven.

Demirci, Karaburun, and Ünlü argue that teacher-centered problems remain the most important hurdle to bypass. (2013) Teachers ultimately decide what they will use in their classrooms, and must be motivated appropriately to incorporate the new technology. Lisner demonstrated that teachers moved forward with GIS on the grounds that it improves their ability to teach the subject, or it improves their students' abilities to think critically about the material. Yet most teachers approach GIS from the perspective that it will be difficult to learn, time-consuming to incorporate into their lesson plans, and could prove damaging to their careers (should their students fail to demonstrate success) due to their decision to risk teaching with methods that are not supported by their administrations. (2008) Similar findings regarding the impact of insufficient administrative support in other research have led many to advocate transitioning to a top-down approach. (Demirci, Karaburun, and Ünlü 2013, and Kerski, Demirci, and Milson 2013) In particular, Kerski, Demirci, and Milson noted that GIS use spread most rapidly in countries where its use was mandated as part of the national curriculum. Regardless of the model selected, bottom-up or top-down, research must convince educators and administrators that a transition benefits their field.

Very little research exists that links GIS to increases in student performance on standardized tests or in classroom environments (Kerski, Demirci, and Milson 2013). In fact, in 2003, Kerski noted that GIS did not produce measurable increases in standardized performance. More recently, in 2010, Liu et al. published their study on problem-based learning (PBL) using GIS. They found that while GIS methods increased higher level thought in the experimental group, the control group performed better at recall and standard memorization tasks. Unfortunately, most standardized tests for the social sciences continue to require students to memorize important dates and events as a large component of their evaluation. Once again, research failed to demonstrate why teachers should transition to GIS in their classrooms.

In 2013, this evidence gap led Kerski, Demirci, and Milson to recommend establishing a research base to demonstrate why GIS makes a difference in secondary education. They recognized that to move forward with implementation, GIS had to prove itself relevant and useful in the classroom setting. Research and training cannot stop at how to supplement lessons with GIS. As Kerski, Demirci, and Milson articulate in their findings, it must demonstrate why GIS is an improvement to traditional methods. (2013)

2.2 Related Work with Visualization Methods

Baldwin articulated the primary question at the center of most visualization research in a manner that bears repeating. How do you communicate temporal and spatial change while simultaneously, effectively communicating the story that the data has to tell? (2014) Complexity increases as multiple sources of data are fused to form a common picture. It is not sufficient to record the data and hope that the user will interpret its meaning appropriately. Visualization methods should be chosen for their ability to communicate to the user in the most effective and efficient manner. Context matters in this endeavor, requiring consideration of the intended audience. Unfortunately, the current body of literature supports the use of static maps in most settings.

Anderson designed his study to conduct an empirical consideration of static and dynamic map representations depicting homicide patterns in Chicago. He selected small multiple map displays for his static visualization method and time series, animated maps for the dynamic representation in his research to take advantage of both tools' ability to visualize the chronological change. He then designed his research tool to assess user effectiveness, efficiency, and preference through completing a series of choropleth map-based knowledge extraction tasks. Anderson based effectiveness on the user's ability to correctly answer questions and assessed efficiency based on the amount of time the participant required. His findings indicated that users interpreted the data more accurately and required less time to complete each task when using the static products. Interestingly, they also tended to prefer the use of the static maps regardless of whether or not they achieved better results while using them. (Anderson 2015)

Anderson's research poses a direct challenge to pursuing GIS integration in secondary school social studies curriculums. Based on his research, one could fairly conclude that students are better served by continuing to use the static classroom products already in use. In addition to the performance variables, Anderson's user preference findings are particularly challenging. Animated visualizations are commonly thought to be more visually appealing and desirable. (Anderson 2015) However, Anderson's research confirmed findings from previous studies that argue that animated products may, in fact, be too complex and distracting for practical use.

Tversky, Morrison, and Betrancourt argue that in almost all cases where animated products have out-performed their static counterparts, factors other than the dynamic animation explained the variance. (2002) They concede that by the congruence principle, which states that the content and format of the visualization method should match the concept conveyed, one would expect animated products to excel at demonstrating change over time. However, in practice, most studies demonstrate that static tools yield equivalent, if not higher learning results. Tversky, Morrison, and Betrancourt go on to argue that in those cases where animated products outperformed their static variants, the animated products provided additional detail or created opportunities for interactive engagement.

The apprehension principle, which implies that visualization methods must be accurately perceived and appropriately conceived, explains why animated products continuously fall short despite their assumed advantage and visual appeal. Tversky, Morrison, and Betrancourt identify that the disconnect between expectation and performance likely reflects the user's perceptual and cognitive limitations to rapidly process the animated product. This justification also explains why incorporating interactivity into the design improves performance. Interactivity is a proven instructional method that has a demonstrated record of improving learning. (Tversky, Morrison, and Betrancourt 2002)

Lowe writes about two possible causes that prevent users from properly processing information through animations. The first reason he articulates directly correlates to Tversky, Morrison, and Betrancourt's findings, the user is overwhelmed by excessive information processing demands. The second reason lends further credence to why adding interactive features to the dynamic visualization model improves learning. At the same time that users are being overwhelmed by excessive information, they are being underwhelmed due to the passive nature in which they engage the material. (Lowe 2003)

In reading these findings, one would be hard-pressed to conclude that dynamic products could provide benefit to teachers and students in the classroom. However, context matters. Definitions matter. This chapter began by defining dynamic visualization methods as those that enable the user to manipulate the data and choose how they wish to visualize the information presented. By this definition, an argument could be made that animated maps, as they have been tested in the past, are in fact static. Once published, the user is forced to visualize the data as the creator intended. That is the very definition of static. The fact that the image moves does not necessarily mean that the product is any more malleable or interactive than a paper map. Much as the planimetric map can be argued as dynamic due to its ability to facilitate layered analysis, the animated map can be classified as static for its inability.

Because context matters, visualization research geared toward GIS integration in secondary school curriculums must consider the intended audience. Children interpret data differently than adults. Therefore, standard map practices appropriate for adults, may not translate in a secondary classroom environment. While prior visualization research should not be discarded completely, it should be considered in light of its context and setting. (Slocum et al. 2001) Unlike previously discussed examples, this study employed a classroom-based research model. This decision created the opportunity to identify findings amongst the intended population that further GIS integration in the classroom would impact most.

2.3 Opportunities for GIS Integration in History Classrooms

Mares and Moschek identify two aims that teachers should consider when teaching space in history. The student should understand that space has evolved over time, and they should be able to recognize and reflect on the way that their own views shape the way that they consider historical space. In order to fully realize the temporal deviations of space, students must be able to capture and critically analyze the impact of human activity on space and the way in which the natural environment shaped human actions. (2013)

Mares and Moschek argue that GIS' dynamic nature creates unique teaching opportunities for educators to help students become aware of their preconceived images of historical space that the traditional use of static printed maps, pictures, and texts cannot duplicate. (2013) Story maps are particularly well suited for these objectives. Put simply; students learn better through increased interaction with data, and particularly through direct, gesture-based manipulations. (Blaser, Sester, and Egenhofer 2000) The primary reason for this stems from the way that humans record and recall information.

Unlike short-term memory, long-term memory has an infinite capacity to store information. The challenge for the educator and the student is to get information to make the transition to long-term memory. As a general rule, the transition depends on two factors; how well the new material relates to previously learned ideas and the level and depth of processing applied to the data as the student learns the lesson. Once transitioned, the student's ability to retrieve information from long-term memory depends on the number and strength of connections formed between the new information and other concepts. (Heuer 1999) The interactive nature of Story maps and their gesture driven manipulation increases the depth of processing that students employ as they learn new lessons.

Mares and Moschek champion the use of GIS in the classroom to encourage student participation and critical thought. However, they caution against giving students too much leeway too quickly. (Mares and Moschek 2013, 67). In addition to the risk of frustration from poorly understood tools and processes, students run the risk of getting "lost" in a virtually limitless pool of data if proper measures are not implemented to constrain their environment. This presents an opportunity for Story maps. As opposed to an open GIS where students have complete control over the selection and representation of data, Story maps allow teachers the opportunity to constrain the data available. Although they rely upon live, published web maps, Story maps only relay the data that the author authorizes for dissemination. This increased level of control reduces the risk of distraction and enables educators to design Story maps around their lessons. Because the Story map already contains all of the layers of data the student requires to complete the lesson, Students no longer need to understand how to manipulate GIS software to reap the benefits of dynamic mapping. As a result, the medium should mitigate student frustrations that stem from incoherent workflows.

Chapter 3 : Research Design and Methods

In order to test the study's research questions, and assess the applicability of static and dynamic maps amongst the intended audience, the study developed and executed a classroom research experiment. The classroom experiment took place over a period of two weeks, with two distinct iterations of the study conducted with each group. The first iteration of the study exposed students directly to the research tool. The control group worked with static tools modeled after what classroom teachers currently employ in their lesson plans, and the experimental group explored the dynamic tool. The second iteration of the study occurred two weeks after the first iteration and asked the students to recall the information that they learned from the tool to complete the required tasks.

Between iterations, students retained access to the spatial tools and lesson content for self-study in order to provide further opportunity for exposure. The control group (Static) took the packet home with them, and additional copies of the study tool remained in the classroom in case students lost access to their original materials. The experimental group (Dynamic) retained access to the Story Map online, and could review the product using school computers, personal computers, tablets, or smart phones as they desired. To ensure students remained focused between iterations, the classroom teacher provided reminders periodically throughout the two weeks. Figure 2, below, presents a graphic depiction of the study's timeline for execution.

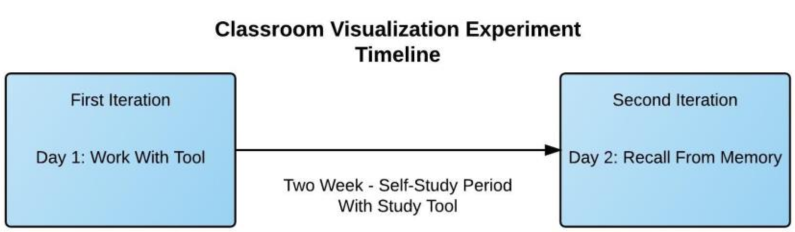

Figure 2 – Graphic depiction of the timeline for the classroom experiment

3.1 Research Design:

3.1.1. Securing and Protecting the Research Population

To gain access to the necessary student populations, the study required permission from local high schools on Oahu to enter their classrooms and conduct the study. However, prior to reaching out to local administrators, the study had to apply for an exemption for human subjects testing through the institutional review board (IRB). The visualization study qualified for exemption based on two factors. First, although the study meets the definition of research as defined in 45 CFR 46.102, it does not meet the definition of human research. The study does not seek to obtain information about the students themselves, nor does it require the collection of personally identifiable information. Instead, the study employs risk mitigation strategies such as using independently assigned identification numbers in place of student names. Second, according to subpart D of 45 CFR 46.102 and 46.101 para (b) 1, the following conditions merit exemption from human subject research when children are involved:

1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods."
2. Research conducted using educational tests

The study's methodologies fit both conditions. Although the study met both factors, the IRB based their exemption decision primarily on subpart D, criteria 1 and 2.

In addition to securing an exemption for the study through the IRB, Hawaii State Department of Education (HIDOE) needed to approve the data sharing agreement between the researcher and the school, to grant the study access to student information and the classroom environment. Due to the timelines required for obtaining a data sharing agreement, the study narrowed its scope to a single high school. Mililani High School agreed to support the study and provided access to a sufficient sample size of students.

A public school located in an established suburban neighborhood on the west side of Oahu, Mililani is the only high school on the island to achieve a perfect 10 rating from greatschool.org (an online resource that ranks schools based on student standardized test performance). Mililani serves a diverse student population, from multiple backgrounds, and provides access to learning for grades 9 - 12. Due to its proximity to the nearby United States military garrisons at Schofield Barracks, Hunter Army Airfield, Joint Base Pearl Harbor-Hickam Airfield, and Fort Shafter, Mililani hosts a large number of military families. From the study's perspective, military students add a unique variable to the classroom-based research thanks to their varied educational experiences from multiple regions around the world.

The study presented the high school administrator with a presentation describing the purpose of the study, along with its intended research design and methodologies. In line with the findings from previous studies, the principal conditionally approved the study, but left the ultimate decision to support the research in the hands of the classroom teacher. The study provided the same materials to the classroom teacher, as well as conducted a phone interview to further clarify the research goals and intended experiment design. Once approved, the study provided two forms of written notification to student parents to provide them with an opportunity to prevent their student from participating in the research. Digital copies of the IRB approved consent/assent form went to the school, and paper copies went home with the students for their parents to review and sign. The study then asked the students to return the forms directly to their teacher to protect the student's anonymity during the study.

The study provided the teacher with a spreadsheet of pre-defined participant identification numbers. Upon receiving the student's signed permission form, the teacher recorded the student's name adjacent to the next available number. From that point forward, students identified themselves by their participant identification number. Students who did not return a signed consent form did not receive participant identification numbers, and did not participate in the study.

Initially, 116 students returned signed consent forms. However, the study required each student to be present on both days of the study for their data to be included in the results. As a result, the final study population totaled 101 students; 51 students assigned to the control group (Static), and 50 students assigned to the experimental group (Dynamic). Table 1 on page 20, describes the population demographics for the two groups. Due to privacy considerations for the students participating, the study did not collect extensive demographic data relating to race, nationality, income level, previous exam scores, or school performance. The study did capture gender and age at the school's request.

Table 1- Study Population Demographics

	Control Group (Static)	**Experimental Group** (Dynamic)
Population Size	51	50
Gender:		
Male	20	24
Female	31	26
Age (Range 14 – 18):		
Mean Age	16	15
Mode Age	15	15

The study assigned students to the control group or experimental group by class. Both, the school administrator and the classroom teacher, preferred that the study leverage the entire student population assigned to the classroom teacher in order to mitigate the impact of the study on teacher's daily lesson plans. This worked in the study's favor, as it made for a simple, random, division of students. Both research groups included three full class periods of students. The study assigned periods 1, 6, and 7 to the control group, and periods 2, 3, and 4 to the experimental group. Using periods 2 through 4 for the experimental group facilitated the study's ability to secure computers. Since they were the first three periods of the day (Period 1 did not hold class during the first day of the study), the study only required access to computers for half of day. The study then switched to the static tool for the remaining class periods.

3.1.2. Lesson Plan Development

The study's adherence to using a classroom environment defined the time available for each portion of the experiment. Two iterations of the study were conducted, each within a standard 55 minute class period. The first iteration of the study focused on measuring the student's ability to extract information using the given set of tools; standard static maps for the control group, and a dynamic, Story Map for the experimental group (Dynamic). The second iteration of the study measured the student's ability to retain information, and the transition of ideas from short term to long term memory. Both iterations afforded the opportunity to measure critical thought and observe how the spatial tool influenced the way the students interacted with and interpreted the data provided. Table 2, on page 22, illustrates the relationships between the iteration of the study and the study's research questions. Both iterations occurred over a two day period in order to capture each class period; periods 2 through 4, 6, and 7, participated on the first day of each iteration and period 1 participated on the second day.

Table 2 - Relationship Between Study Design and Research Questions

	First Iteration	**Second Iteration**
1. Are there measurable increases in student performance in knowledge extraction?	Observed	Not Observed
2. Does the use of story maps increase the likelihood transitioning ideas from short term to long term memory?	Not Observed	Observed
3. Do story maps facilitate critical thought through active participation with data as it is presented?	Observed	Observed

In order to make full use of the allotted time, the study pre-positioned all research tools at the student's desk prior to the beginning of the period. The control group received a printed copy of the study maps and lesson materials, bound in report folders, while the experimental group used the classroom's computers to access the Story Map. The classroom teacher loaded the link to the Story Map in the class share drive, and a written copy of the web address was projected on the board for students to transcribe manually as required. Both groups received the same exam material, pre-positioned next to their designated study tool, face-down.

The first iteration provided the students in both groups five minutes for familiarization with the study. During this time, the students were reminded that participation in the research was voluntary and afforded an opportunity to work on an alternative activity as provided by their teacher. Students that refrained from returning their signed consent forms were separated from the study population at this time as well by the classroom teacher. The remaining students continued with the study.

Both research groups received the same lesson plan for the study in order to isolate the tool. The lesson began with ten minutes of instruction provided by the researcher designed to broadly introduce the topic and explain the rationale for selecting the subject material to the students. During this period, the researched confirmed that no participants entered the study with pre-existing knowledge of the lesson material. Following instruction, the students received instruction to flip over their exam material and begin working on it, using their designated tool to identify the answers to the questions. While working on their exams, the classroom teacher took a copy of the study's participant list around for the students to reference to record their participant identification number on the exam packet. At the end of the class period, students returned their exam to their teacher. Table 3 (below) describes the breakdown of time allotment during the first iteration of the study.

Table 3 – Description of Time Allotment Used During the First Study Iteration

Time	Activity
10 Minutes Before Class	Pre-Stage Study Tools at Each Desk
Class Begins	
5 Minutes	- Introduce Study - Separate Study Population from Non-Participants
10 Minutes	- Introduction to the Bascom Affair - Explain the Rationale for Choosing the Topic
40 Minutes	- Students Work on Exam Packet Using Their Designated Tool - Classroom Teacher Issues Participant IDs - Classroom Teacher Observes and Records Participation
Class Ends	
5 Minutes	Classroom Teacher Collects Exams and Confirms Participant ID For Each Student

In addition to collecting data from the exam itself, the first iteration of the study also observed student engagement with the material. While the students worked on their exam packets, the classroom teacher observed each student to assess their level of engagement with the study tool. The teacher recorded the initial assessment within the first ten minutes, and then re-assessed each student at the midway mark, and ten minutes prior to the end of the class period.

The study only recorded successful engagement for students that remained on task throughout the entire class period.

Similar to the first iteration of the study, the second iteration pre-staged the exam tool at each student's desk prior to the beginning of the class period. Once again, the first five minutes of the period were used to segregate the research population from the students not participating in the study and re-introduce the study to the participants. However, unlike the first iteration, the participants received no further instruction following the initial re-introduction. The students used the remaining time in the period to complete the exam; this time without the use of the study tool. Students completed the second iteration of the study with the information that they remembered from interacting with the tool. Table 4, below, provides the distribution of time used for the second iteration of the study.

Table 4 – Description of Time Allotment Used During the Second Study Iteration

Time	Activity
10 Minutes Before Class	Pre-Stage Study Tools at Each Desk
Class Begins	
5 Minutes	- Introduce Study - Separate Study Population from Non-Participants
50 Minutes	- Students Work on Exam Packet Without Their Designated Tool - Classroom Teacher Issues Participant IDs
Class Ends	
5 Minutes	Classroom Teacher Collects Exams and Confirms Participant ID For Each Student

3.1.3. Exam Tool Data

The exam tool provided the study with the data required to assess student performance and answer the study's research questions. To avoid introducing a new variable to the study, both groups used the exact same exam tool, and method of filling it out. Divided into five sections, the exam consisted of a total of 24 questions. For the second iteration, the study introduced a sixth section requesting information about how the student interacted with the cartographic tool during the two week self-study period.

Each of the five sections employed a unique question format. Section one included ten fill in the blank questions; section two provided two true or false statements; section three asked the student to respond to two short answer questions; section four included six questions focused on spatial analysis skills that required the student to directly interpret data from the study's maps; and section five gave the students an opportunity to respond to four essay questions to elaborate on how they interpreted the lesson material. Most sections included a question that could be approached and answered in multiple ways to assess critical thought. To confirm the student's thought process, the essay questions provided the student an opportunity to elaborate on similar ideas queried in those questions. For a complete copy of the exam tool used in the study, refer to Appendix E. Table 5 below further illustrates the data collected from the exam tool, and identifies the questions that correlated in the study.

Table 5 – Description of Exam Tool Sections and Data Collected

Section	Question Format	Quantity	Points	Correlation
Section One	Fill in the Blank	10	1 Each	#10 to Essay 2&3
Section Two	True or False	2	1 Each	#11 to Essay 1
Section Three	Short Answer	2	1 Each	N/A
Section Four	Spatial Analysis	6	1 Each	#15-16 to Essay 4
Section Five	Essay	4	5 Each	N/A
Section Six (Second Iteration Only)	Study Assessment	6	0 Each	N/A

3.2 Selection of Appropriate Lesson Material

Hawaii General Learning Objectives establish the opportunity for increased use of GIS in their classrooms by focusing on developing student skillsets to use a variety of technology effectively and ethically, and creating opportunities to improve complex critical thinking and problem-solving skills (Hawaii Standards 2005, 2). The study design intentionally ties into existing Hawaii state standards for secondary school social studies curriculums to test the students' ability to interpret data from the maps with ties to stated learning objectives appropriate to their grade level. However, to assess the performance of each visualization method appropriately, the study required that students enter the classroom without sufficient background information on the topic of instruction. By the time students reach high school, they are familiar with many standard narrative topics. Therefore, the study intentionally selected an obscure event from United States history to mitigate the risk of pre-existing knowledge providing students with an advantage on the examination materials.

In February 1861, the Bascom Affair triggered 25 years of war between the United States government, and the Apache Indians. (Ball 1980, 25; Sweeny 2014, 13; and Mort 2013) Few adults understand the events that occurred during United States' westward expansion in the nineteenth century, particularly those that occurred in 1861 in line with the outset of the American Civil War. The associated conflicts with North America's native populations are broadly interpreted as the Indian Wars and receive very little attention in standard curriculums. Fortunately, lack of attention does not equate to lack of value. The Bascom Affair provides the opportunity for the study to tie into existing state standards without risking the integrity of its findings.

Hawaiian students cover westward expansion and “Manifest Destiny” as part of their standard 8th grade curriculum. Therefore, high school students in the state are familiar with the period. Their prior familiarization enabled the study to meet several state standards by leveraging the Bascom Affair to provide new information to an already existing knowledge base. The study ties into Hawaii state standards 1, 2, 6, and 7, described in Table 6 on page 26, to determine how static and dynamic visualization methods support student learning.

3.2.1. Sources of Historical Data

Because the Bascom Affair is not part of standard high school curriculums, the study had to develop supporting lesson materials. The study relied upon a mix of primary and secondary sources to develop the facts surrounding the event. The bibliography identifies the full list of sources used in the study, but three works deserve focus here. First, Edwin Sweeney’s *Cochise: First Hand Accounts of the Chiricahua Apache Chief*, provided access to valuable primary sources on the Apache War, seamlessly stitched together to follow the timeline of events. Sweeney’s notes cross-reference multiple primary sources to reveal the original author’s bias, and add depth to traditional narratives through the inclusion of official military reports, eye-witness accounts, newspaper articles, and interviews with Cochise himself. These interviews are the closest thing to an autobiography on the great Apache leader and are crucial to understanding the Apache road to war, and motivations for fighting the Americans.

Table 6 – Relationship between Hawaii Content and Performance Standards for Social Studies and the Bascom Affair lesson plan used in the study (Hawaii Standards 2005)

<table>
<tr><td colspan="2">Standard 1: Historical Understanding: Change, Continuity, and Causality – Understand change and/or continuity and cause and/or effect in history</td></tr>
<tr><td>Hawaii Benchmark: No benchmarks identified</td><td>Study Benchmark: Examine the events that led to war between the United States and Apache in 1861</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Identifies the relationship between the United States and the Apache in 1861 prior to Bascom Affair, and articulates the connections between the kidnapping of John Ward’s son, and the actions taken by the United States Army that led to war.</td></tr>
<tr><td colspan="2">Standard 2: Historical Understanding: Inquiry, Empathy, and Perspective – Use the tools and methods of inquiry, perspective, and empathy to explain historical events with multiple interpretations and judge the past on its own terms</td></tr>
<tr><td>Hawaii Benchmark: No benchmarks identified</td><td>Study Benchmark: Examine the Bascom Affair from multiple perspectives: American and Apache</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Identifies their own preconceived biases, articulates how the principal actors perceived the events leading up to the conflict at Apache Pass, and critical differences in each narrative that shape the way the event is viewed today.</td></tr>
<tr><td colspan="2">Standard 6: Cultural Anthropology: Systems, Dynamics, and Inquiry – Understand culture as a system of beliefs, knowledge, and practices shared by a group and understand how cultural systems change over time</td></tr>
<tr><td>Hawaii Benchmark: No benchmarks identified</td><td>Study Benchmark: Examine how failure to understand and account for culture, exacerbated conditions between the United States and Apache</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Identifies cultural misunderstandings that escalated tensions to the point of war and is able to discuss opportunities for intervention that both parties missed.</td></tr>
<tr><td colspan="2">Standard 7: Geography: World in Spatial Terms – Use geographic representations to organize, analyze, and present information on people, places, and environments and understand the nature and interaction of geographic regions and societies around the world</td></tr>
<tr><td>Hawaii Benchmark:
SS.11.7.1 – Trace changing political boundaries under the influence of European Imperialism</td><td>Study Benchmark: Trace changing political boundaries under the influence of American Western Expansion</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Examines the new political boundaries created by American Western Expansion in the present-day American Southwest.</td></tr>
<tr><td>Hawaii Benchmark:
SS 11.7.2 – Use tools and methods of geographers to understand changing views of world regions</td><td>Study Benchmark: Use tools and methods of geographers to understand changing views of the present day American Southwest</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Uses geographic visualization methods to understand changing conceptions of the present day American Southwest.</td></tr>
</table>

Second, Dan Thrapp's *The Conquest of Apacheria*, is known by many scholars of the Apache Wars as the seminal work on the subject. The bibliography comprises 16 pages of sources including manuscripts, unpublished documents, newspaper articles, military reports, government documents, and numerous other primary and secondary sources. Thrapp's research is unparalleled in its exhaustive treatment of the source material. This study relies heavily on his experience and relatively unbiased interpretation of events to ensure accurate treatment of the lesson material.

Third, Terry Mort's, *The Wrath of Cochise: The Bascom Affair and the Origins of the Apache Wars*, provides a significantly different interpretation of the Bascom Affair. Mort's focus on the awkward reality of being a young second lieutenant charged for the first time with leading soldiers to the romanticized version often written about that yearn for war and are born ready to lead helps personify Lieutenant Bascom. Mort does the Bascom Affair justice through his deep analysis of not only the event itself, but the political situation surrounding it, and the education and development of the United States Army and Apache leaders involved. His narrative provides excellent insight into the decision cycles that brought the two nations to war, and helps tie the study's lesson materials to Hawaii state standards.

3.2.2. Sources of Historical Maps, Photographs, and Materials

The study relied on two sources of information to produce its historical maps, photographs, and lesson materials: books and open source, publically available, internet data. Higher quality or more appropriate primary sources may exist, but they are not readily available to the average person. The source materials selected to support this study reflect those that teachers could expect to access for free, and without the requirement for travel. By restricting the study in this manner, the findings reflect outcomes that teachers can realistically expect to replicate in their classrooms.

3.3 GIS Datasets

As identified in Chapter 2, technology requirements to implement desktop GIS programs consistently present a barrier to further implementation. However, thanks to President Obama's ConnectEd initiative and Esri's gift of free ArcGIS online organizational accounts to K-12 educators, teachers now have access to the required tools. In line with the decision to use source materials readily available to classroom teachers, the study decided to employ ArcGIS online to the fullest extent possible to create its visualization tools; the lone exception being the creation of the final published maps that study's static tool employed. By maximizing the use of ArcGIS online, the study remained consistent in its effort to employ replicable methods that educators can develop for their classrooms.

Most of the data required by this study are readily available through ArcGIS online. Table 2, on the next page, describes each layer of data and its availability. Esri provided base maps meet industry metadata standards and required little manipulation for use. In addition to the base maps provided by Esri, the United States Geological Survey provides digital elevation models, and land use/land cover data directly through the search function on ArcGIS online. Likewise, the David Rumsey historic map collection also hosted georectified historical maps for quick overlay through the ArcGIS online search tool. However, since most of the locations in question no longer exist, they had to be recreated from historical records and digitized onto the map.

Table 7 – Spatial Data Used to Support the Study

Dataset	Content	Format	Attributes	Quality
Key Locations	Location of critical events in the Bascom Affair	Vector - Points, Lines, and Polygons	Name, coordinate, description (ranch, military outpost, town, village, etc.)	N/A
Availability: Created for the study; digitized from historical records (See Bibliography).				
Historical Photos	Photos of key persons, locations, and conditions	Raster	Name, description	
Availability: Located through online queries using the Google search engine.				
Base layer	Base Imagery	Raster	Cover SE AZ	Provide 5m resolution of Sonoita and Apache Pass
Availability: ArcGIS online base maps used for this study.				
DEM	Elevation Data for SE AZ	Raster	Covers SE AZ	10 - 30 m
Availability: USGS elevation sets; ArcGIS online utilized to conduct observer point/line-of-sight analysis and viewshed analysis.				
Land use/Land Cover	Soil types, vegetation	Raster	Soil type, vegetation type, height, density, color	30 m
Availability: ArcGIS online provided USGS LULC sets.				
Hydrography	Hydrographic profiles for SE AZ	Vector: points, Lines, and Polygons	Type of water feature, direction of flow, and name	
Availability: ArcGIS online provided USGS NHD data for SE AZ; feature layer depicting the national park visitor trail at Apache Pass identified the natural spring location.				
Historic Maps	Digital renditions of historic maps from the Apache War era	Raster	Georeferenced for use in ArcGIS	
Availability: ArcGIS online provided access to the David Rumsey historic map collection.				

3.4 Data Aggregation

The lesson, and accompanying maps used in the study focus on a 30 day period from January 19, 1861, through February 19, 1861. The study placed special emphasis on two events; the kidnapping of Felix Ward in late January, and the recovery efforts led by Lieutenant Bascom in the first week of February. Both sets of maps, static and dynamic, reflect the overall area of interest in present Southeast Arizona, as well as provide regional level detail for the areas around Sonoita Creek and Apache Pass.

3.5 Visualization Methods:

3.5.1. Static Visualization Tools

The static tool resembled a book, bound in a report folder. The study created six maps and incorporated an additional two open source maps, eight photographs, and a timeline of critical events to visualize the lesson materials for the study. The tool integrated the open source maps, photographs, and timeline into the text of the document to replicate as closely as possible the format in which the dynamic tool portrayed the lesson to the students. The tool incorporated the six maps created for the study at the end of the text, in chronological order. The Decision to place the maps at the end of the tool was made to enable the students to easily separate them from the lesson material and reference them throughout their interaction with the data. For a complete copy of the static tool, in its original format, refer to Appendix A.

The first map created for the study (shown on page 33 in figure 3) demonstrated a macro, state level view, of the Arizona and New Mexico territories. The map focused on showing the student how, and when the United States acquired the territories through a series of annexations, cessations, and purchases in the first half of the nineteenth century. The second map portrayed the same land mass, but from the Apache point of view (Figure 4 on page 34). United States' political boundaries are absent from the map and replaced by shadowed imagery, and polygons depicting the approximate range of Western and Chiricahua Apache land claims. The map purposefully included the title “Indeh” for the Apache peoples, to re-emphasize the portion of the text that described how the Apache refer to themselves.

The study created the first two maps in line with Hawaii Content and Performance Standards for Social Studies number 2 and number 7. (Hawaii Standards 2005) The maps intended to demonstrate changing political boundaries at the time of the Bascom Affair, as well as how both parties viewed the landscape. The study employed both maps in an attempt to redefine the student's preconceived ideas and enable the student to analyze the Bascom Affair in the context of its historical space and time. (Mares and Moschek 2013)

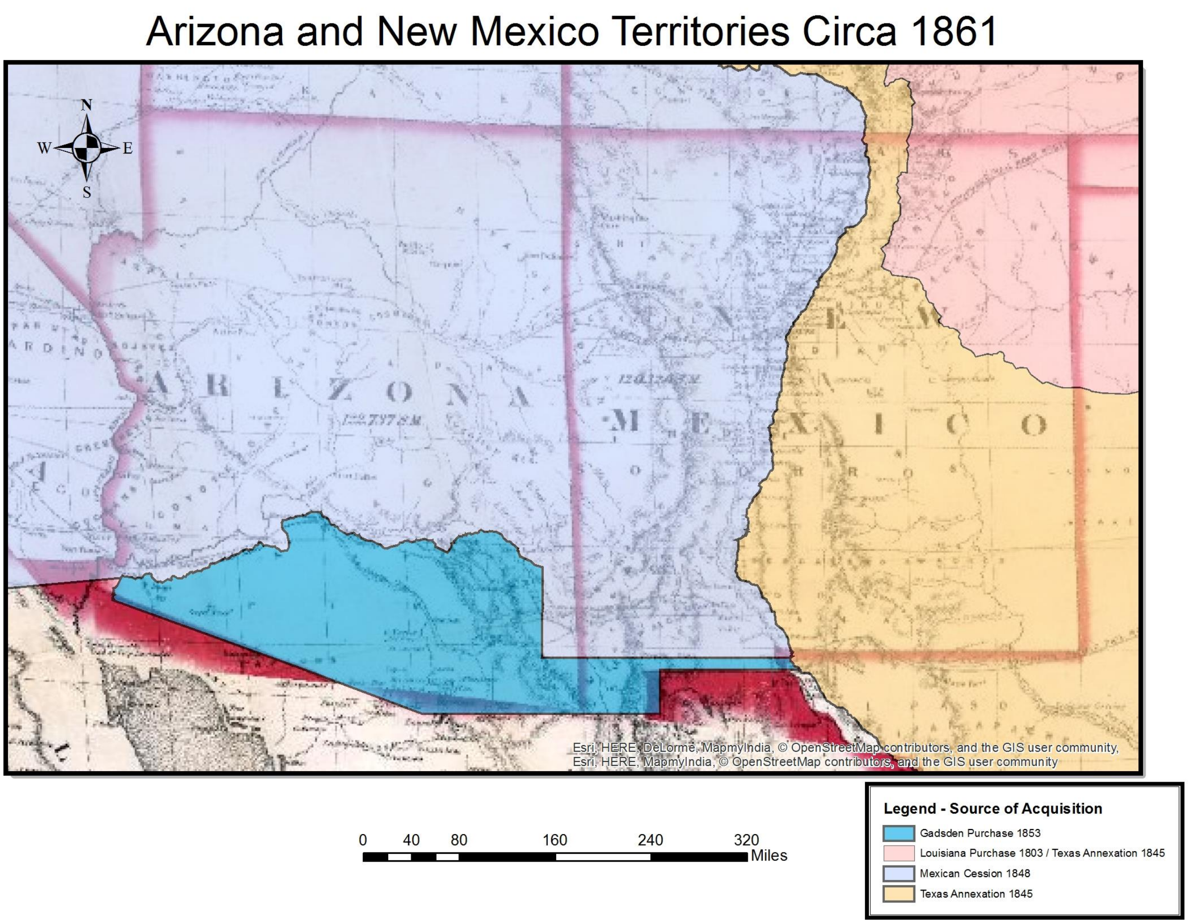

Figure 3 – Map of the Arizona and New Mexico Territories; date and source of land acquisition are portrayed in the map's legend.

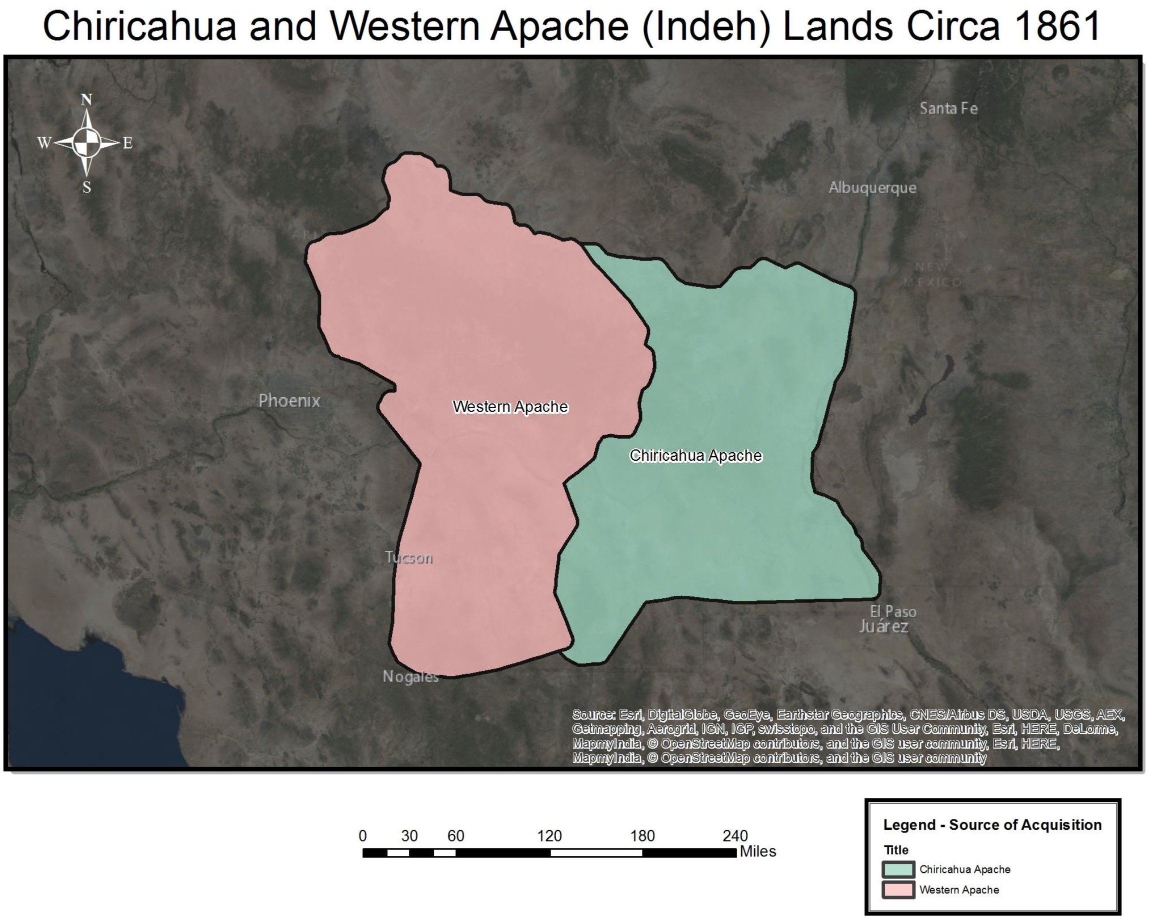

Figure 4 – Map of Western and Chiricahua Apache lands at the time of the Bascom Affair in 1861; polygons represent approximate ranges reconstructed from historical accounts and do not include portions of Apache territories from other bands or south of the U.S. – Mexico border.

The third map (Figure 5 below) reflected all four state standards targeted in the lesson plan for the study. It defined the location of the Arivaipa Group of the Western Apache and included the kidnapping site at John Ward's Ranch for reference. Of note on the third map, the United States' political boundaries are absent, and the Apache land claims are emphasized. In addition to demonstrating where the kidnappers originated, Map 3 helped the student understand which bands claimed the lands surrounding the kidnapping site and begin to understand the faulty logic behind accusing the Chiricahua Band.

The Arivaipa Group of the Western Apache Band

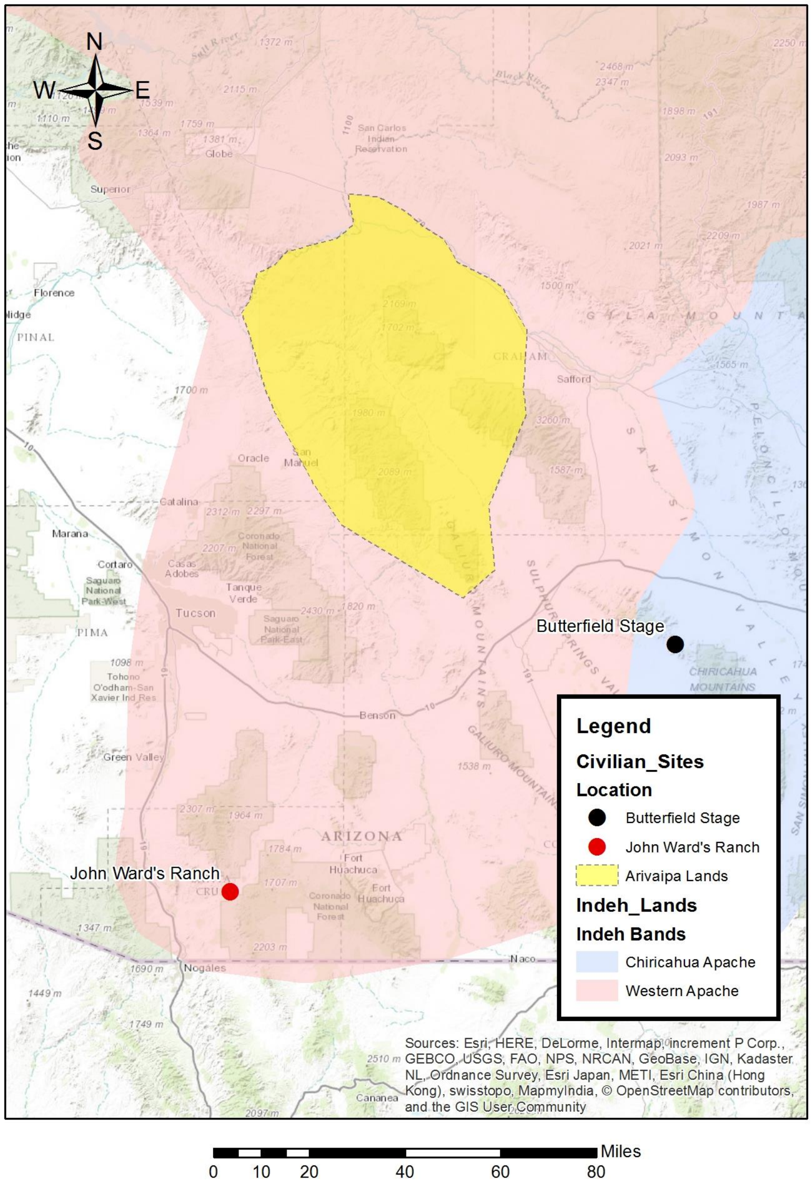

Figure 5 – Map depicting the Arivaipa Apache Group of the Western Apache Band

Finally, the fourth Map (figure 6 below) provided a macro view of the key locations during the Bascom Affair, while maps five and six (figures 7 and 8 on page 35 and 36 respectively) focused on a micro level view of the incident site. Map four depicted the kidnapping site, location of the United States Army garrison at Fort Buchanan, the route used by Lieutenant Bascom to approach Apache Pass, and the location of the Bascom Affair; map five portrayed the line of sight analysis looking from positions in Apache Pass into the valley to observe Bascom's approach; and map six provided a smaller scale view of the critical sites at Apache Pass to provide additional detail not available in map four.

The Bascom Affair

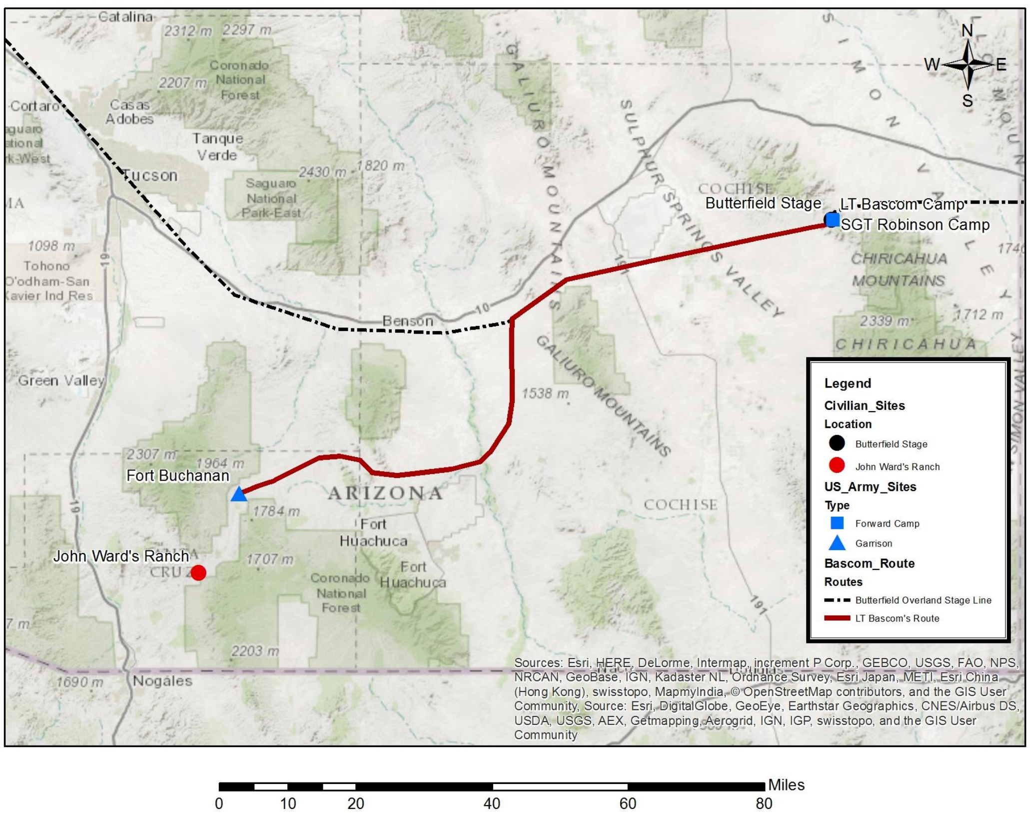

Figure 6 – Macro level view of the key sites and routes involved in the Bascom Affair

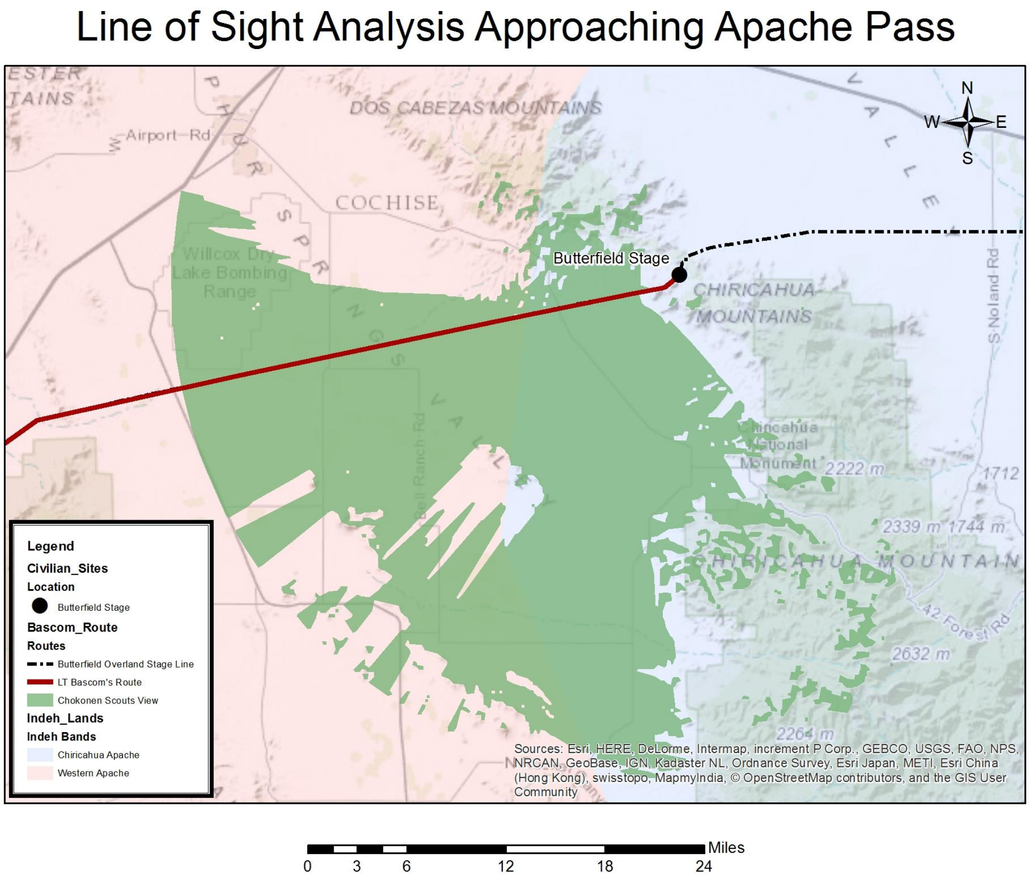

Figure 7 – Line of sight analysis portraying the approximate range at which Apache Scouts identified Lieutenant Bascom’s approach into Apache Pass

The study used this series of maps to focus on Hawaii State Standards 1 and 2. The three maps illustrate the cause and effect, linear nature, of the incident and enable the student to trace the events spatially and temporally on the map. Specifically, the study relied on the micro level maps to illustrate the Apache point of view going into the meeting with the United States troops. They demonstrated the Chiricahua’s awareness of Bascom’s approach, and their willingness to allow him to advance and make camp near their positions in the vicinity of the spring in Apache Pass. (Hawaii Standards 2005)

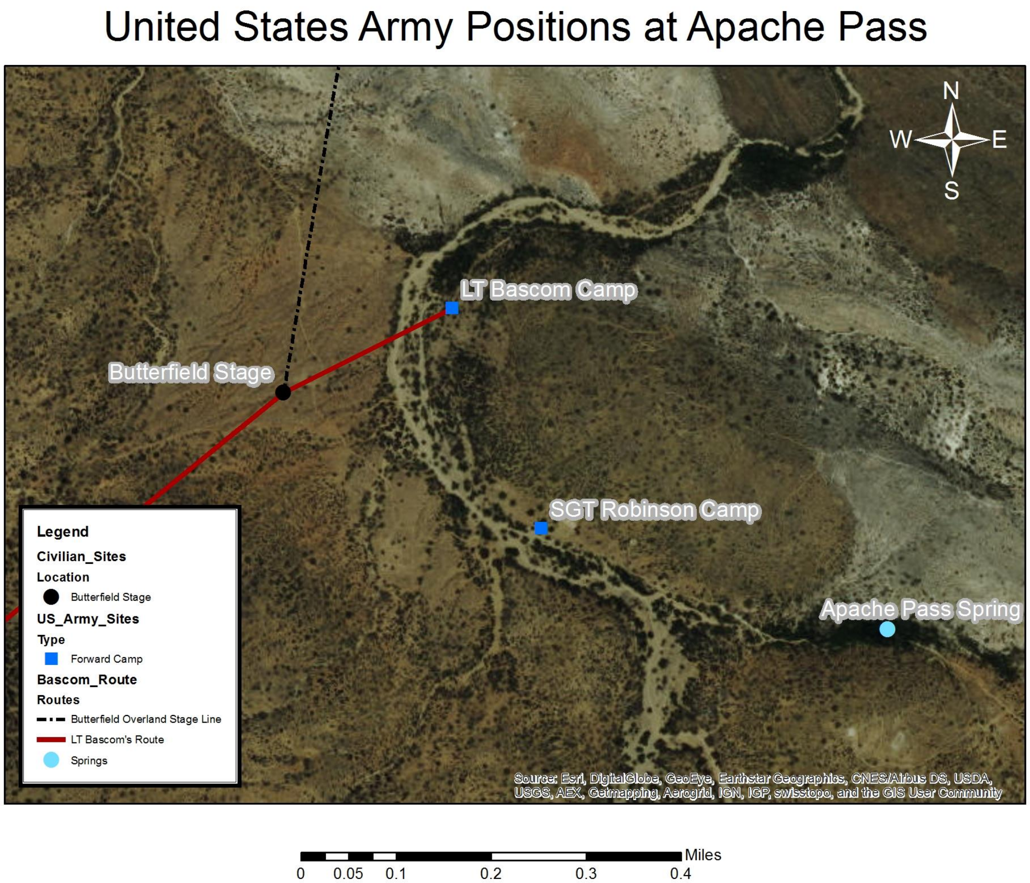

Figure 8 – Micro level view of the United States positions in Apache Pass, and their proximity to the spring used by the Chokonen Apache Group.

The study designed the static tool to replicate standard texts and maps that classroom teachers presently use in their curriculums. Teachers employing static products already make use of additional visual aids to enhance their lesson plans. Therefore, it made sense to use the same sketch maps, historical and present day photographs of Apache Pass and key personalities, and timelines to enhance the delivery of lesson materials for the students in the static tool that the dynamic tool employed in its format. Similar techniques are presently employed regularly in classrooms and are in line with standard teaching practices.

3.5.2. Dynamic Visualization Tool

The story map used in the study was created using the tabbed map series application created by Esri, and hosted on ArcGIS online. Each of the six maps identified in section 3.5.1 resides within the tabs of the story map. However, in addition to the static variants, the Story Map hosts a live web map version of the data. Students had the opportunity to remain on any given tab for as long as required, enabling them to navigate freely between them at their pace. Figures 9 through 16 on pages 37 through 41 depict screen captures of each of the dynamic tool's tabs used in the study. In screen captures with the web maps depicted, the legend and map overview tabs have been maximized. However, students had the ability to minimize both tools at will in order to view a greater portion of the web map during the study.

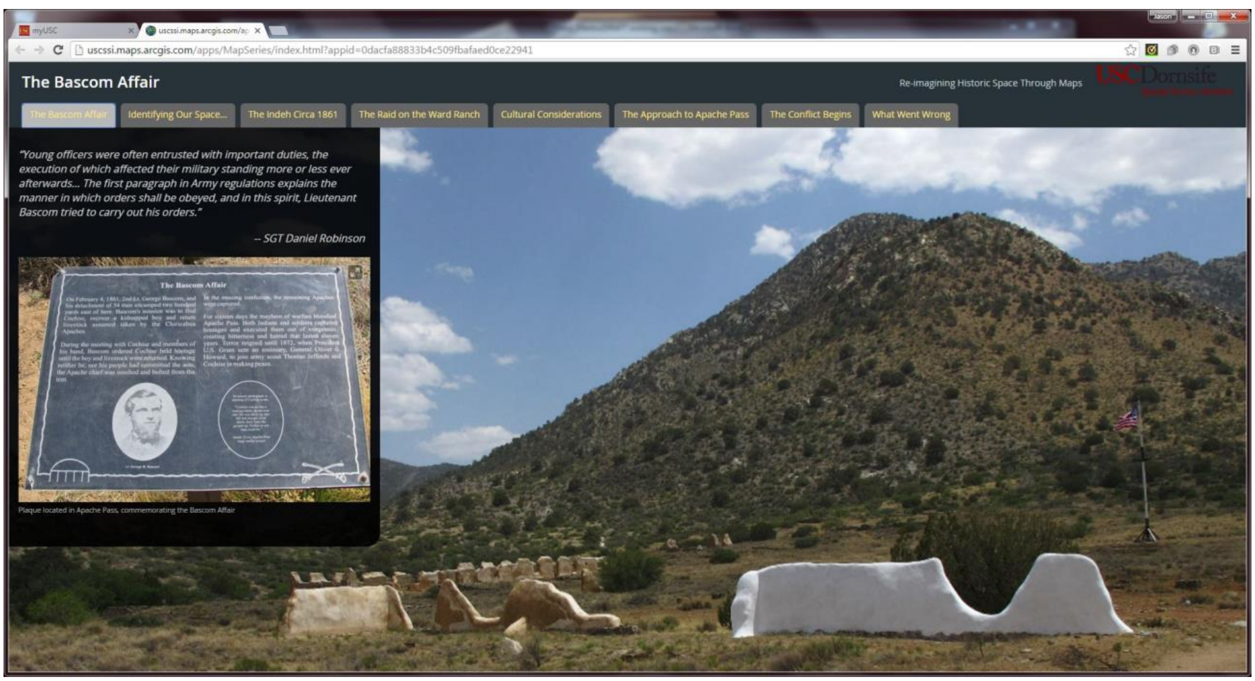

Figure 9 – Screen capture of the title tab that students saw when they first navigated to the Story Map.

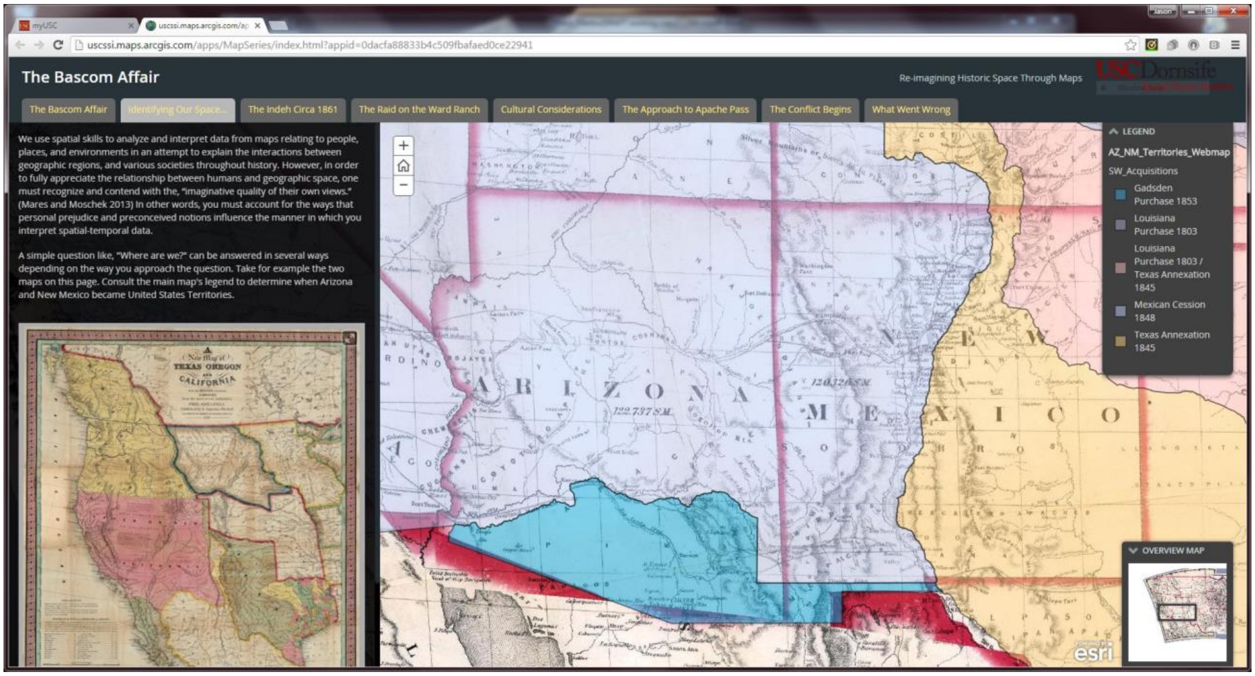

Figure 10 – Screen capture of tab 2 entitled, "Identifying our Space" in the Story Map; the web map from tab 2 equates to Map 1 in the static tool.

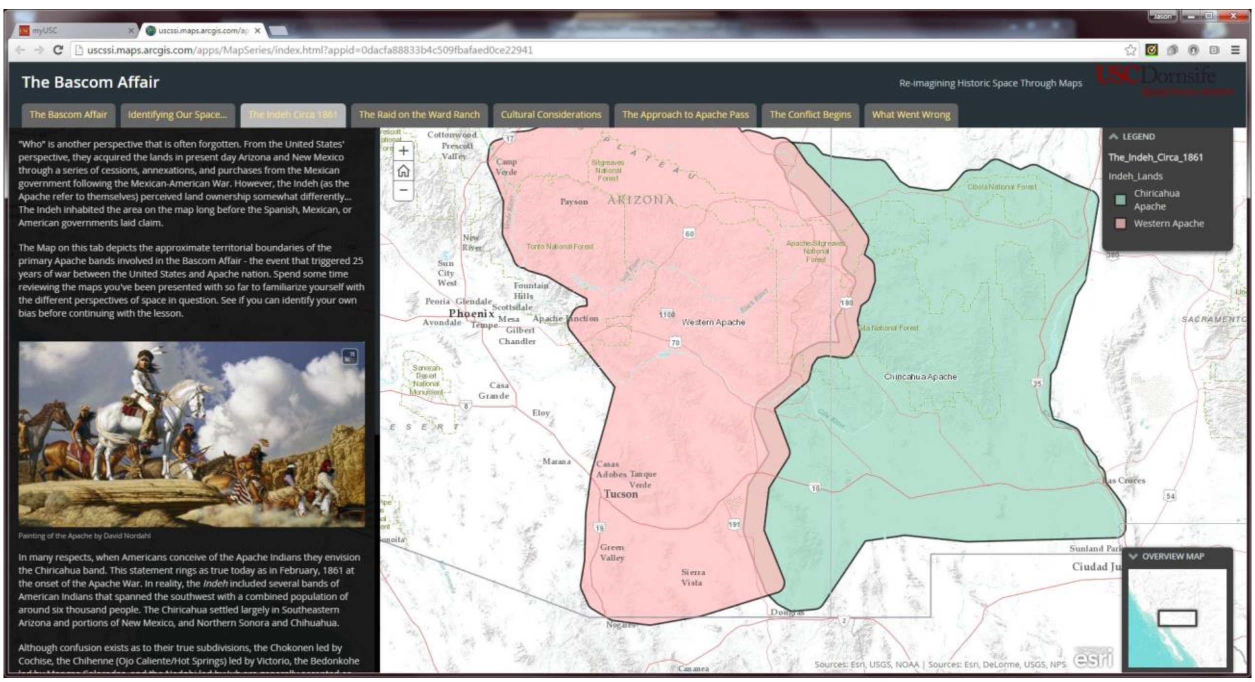

Figure 11 – Screen capture of tab 3 entitled, "The Indeh Circa 1861" in the Story Map; the web map from tab 3 equates to Map 2 in the static tool. The base map used in the web map was lightened to make it easier to read on computer monitors.

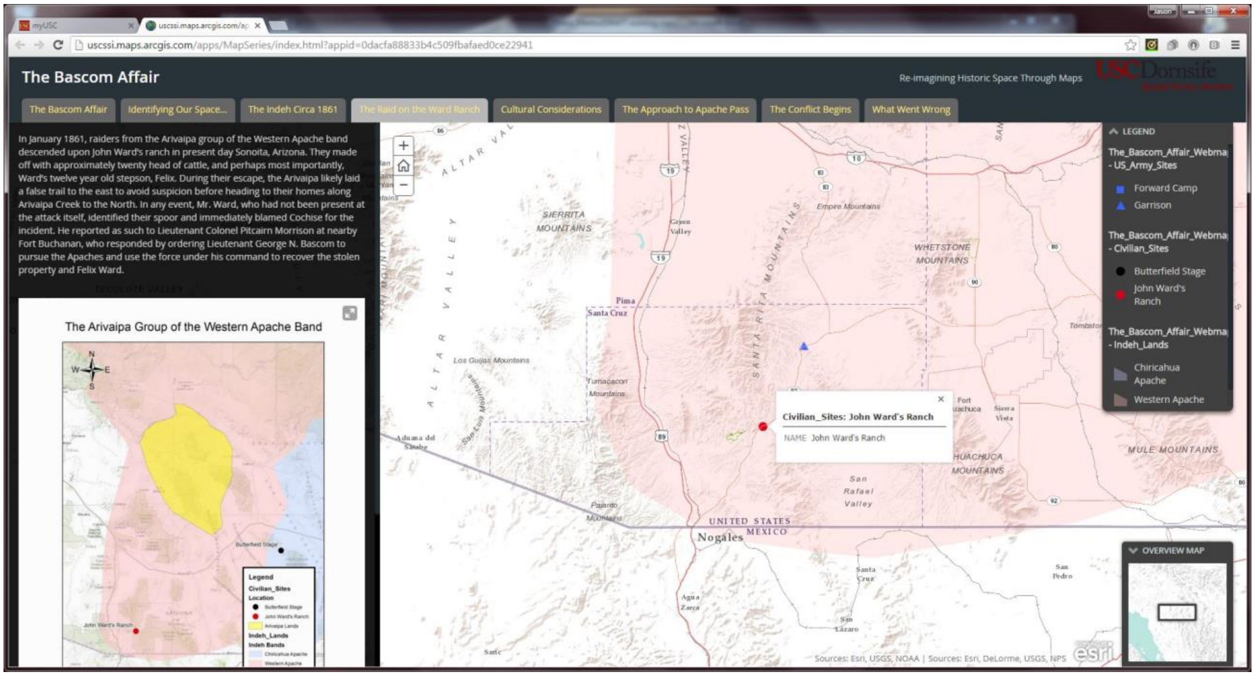

Figure 12 – Screen capture of tab 4 entitled, "The Raid on John Ward's Ranch"; Map 3 from the static tool embedded in the narrative with the ability to maximize the map on screen by clicking the top right corner of the image.

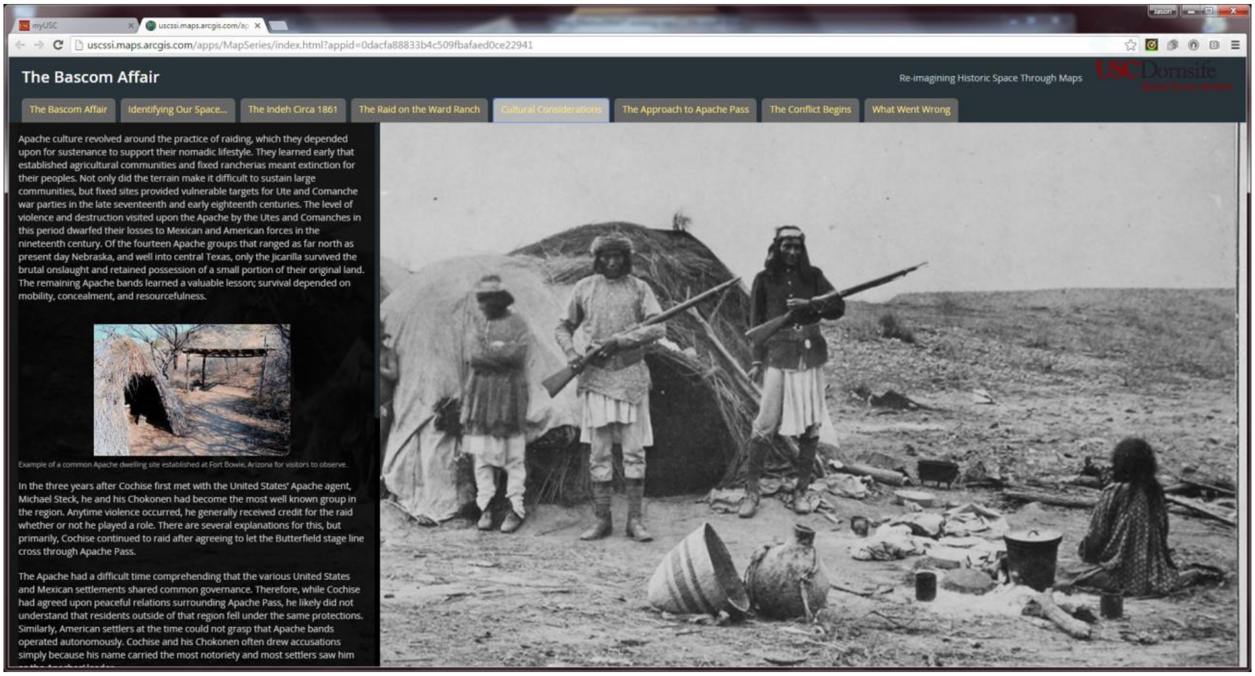

Figure 13 – Screen capture of tab 5 entitled, "Cultural Considerations" in the Story Map; no maps included in this tab.

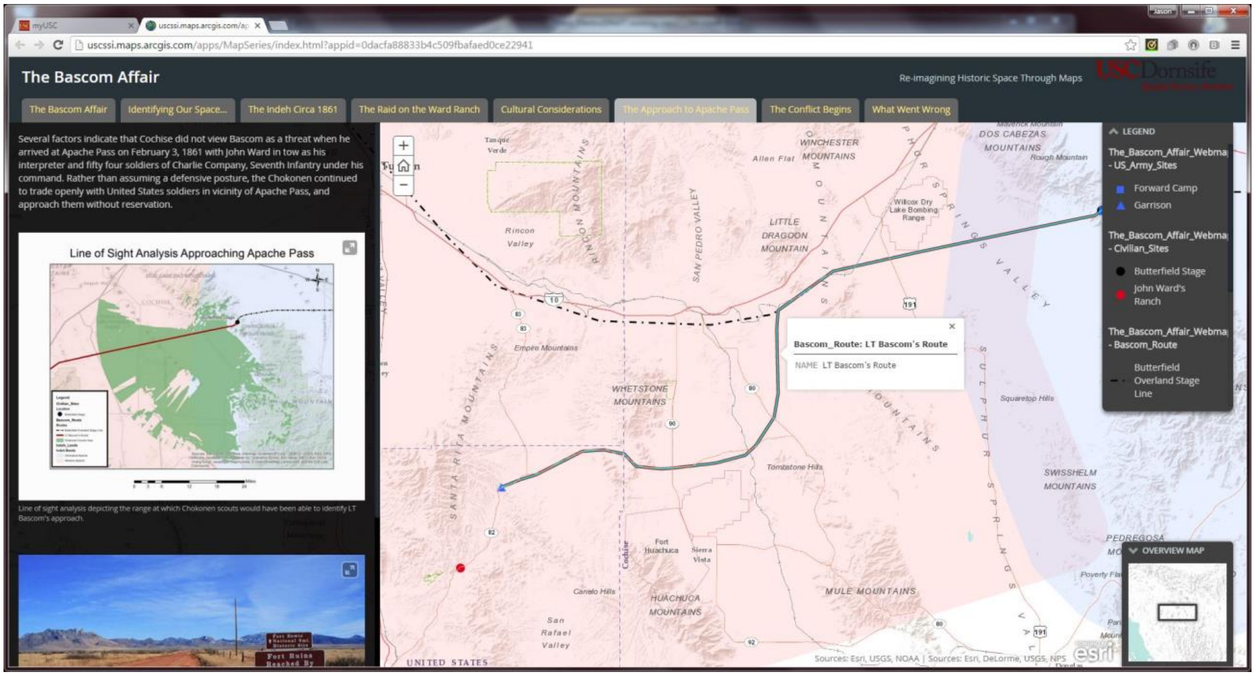

Figure 14 – Screen capture of tab 6 entitled, “The Approach to Apache Pass” in the Story Map; web map equates to map 4 from the static tool. Map 5 from the static tool embedded in the narrative with the ability to maximize the map on screen by clicking the top right corner of the image.

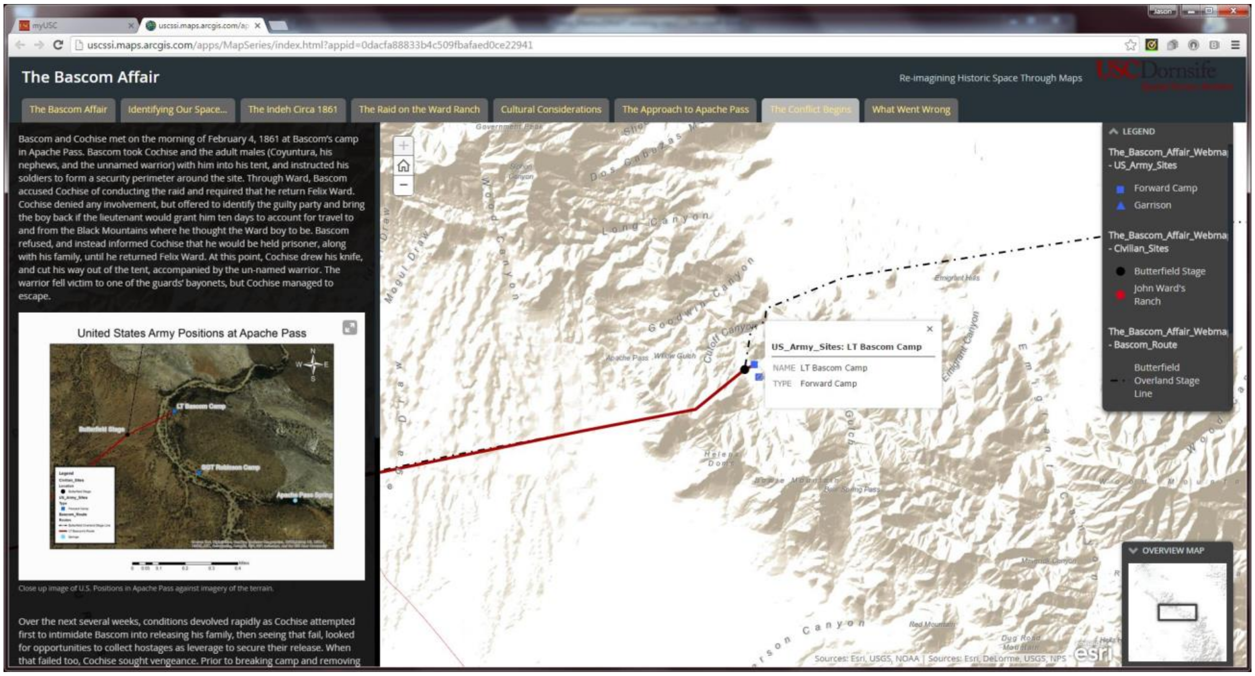

Figure 15 – Screen capture of tab 7 entitled, “The Conflict Begins” in the Story Map; web map equates to map 6 from the static tool, and is further embedded in the narrative on the left.

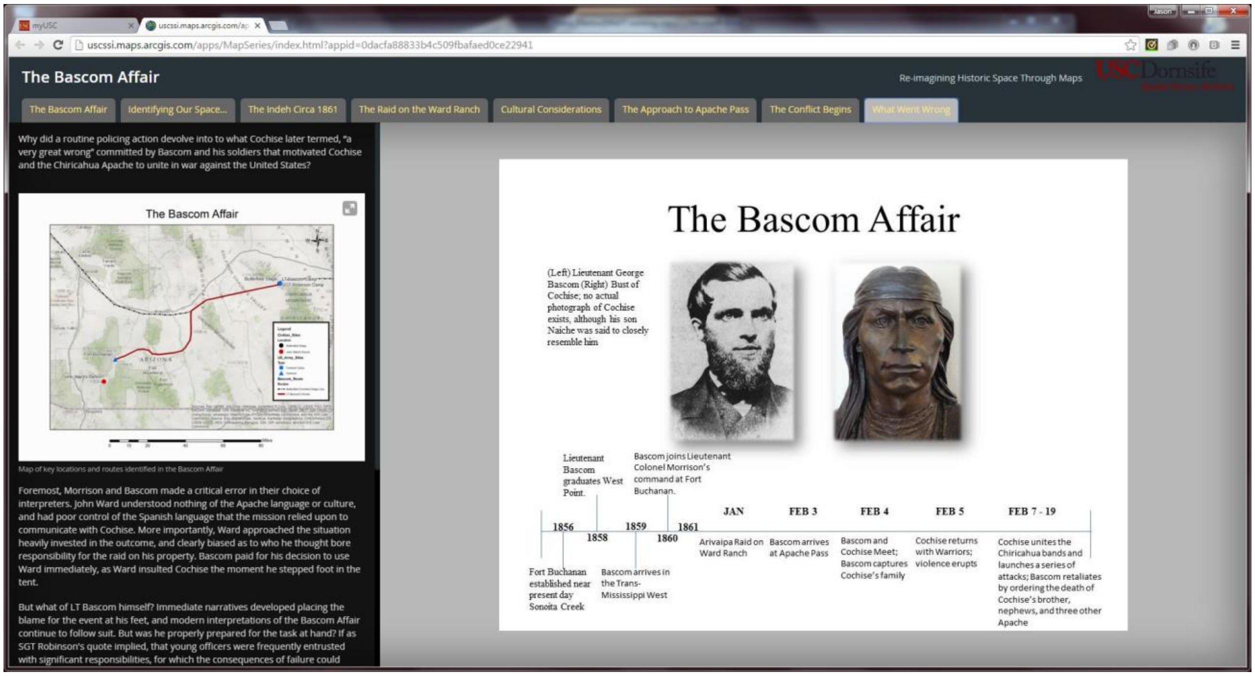

Figure 16 - Screen capture of tab 8 entitled, "What Went Wrong" in the Story Map; map 4 from the static tool embedded in the narrative with the ability to maximize the map on screen by clicking the top right corner of the image.

Unlike the control group (Static), additional visualization aids in the experimental group (Dynamic) were built directly into the story map. The study embedded open source maps, photographs, and timelines in the scrolling narrative on the left side of the map or as a substitute for the web map in the main frame (tab 5 and tab 8). At times, the study also embedded maps developed for the static study tool into the narrative panel driven by the web map's lack of a scale bar in the story map tool. Incorporating the static maps as an image in the dynamic tool provided students in the experimental group the opportunity to answer the spatial analysis questions in the exam tool while maintaining uniformity in the data presented to the two groups in the study.

3.5.3. Data Uniformity

The study's focus is to test the visualization methods. Therefore, in order to isolate the two tools, students from the control group (Static) and experimental group (Dynamic) received access to the same data in their lessons. The study ensured that all data presented in the story map, also be included in the static variant in order to isolate the delivery mechanism. Toward that end, the static tool even reflected the tab titles from the dynamic tool. However, the static tool incorporated the tab titles as section breaks in the narrative packet. The only variation between the control group and the experimental group was the student's ability to manipulate the data in the web map, and the medium of delivery.

3.6 Methodology for Analyzing Findings:

The study drew from Ben Anderson's methodology to develop its methodology for assessing knowledge extraction and increases in long-term memory. The study carried two of Anderson's factors, effectiveness and efficiency, to develop its findings. (Anderson 2015) To assess critical thought, the study incorporated Bloom's Taxonomy of Cognitive Learning Skills, modelled after the research conducted by Liu Et Al. (2010) By incorporating methodologies from prior visualization research in a new environment, the study adds to the body of current knowledge. Specific methodologies employed by the study to answer each of its research questions are discussed in greater detail in sections 3.6.1 – 3.6.3.

3.6.1. Determining student performance in knowledge extraction

Research question #1 asked, are there measurable increases in student performance in knowledge extraction? To answer this, the study adopted Anderson's criteria of effectiveness and efficiency to measure the student's ability to extract information from their given study tool to respond to questions on the exam tool. The study measured effectiveness by recording the number of points earned divided by the number of points possible in each section of the exam tool for each student. The study then determined the mean scores achieved by each study group on each section and compared them to determine which population performed knowledge extraction tasks most effectively. Independent samples (two-tailed) t-tests compared the mean scores from each section, from each study group, to determine statistical significance.

The study measured efficiency somewhat differently than Anderson's model. Whereas Anderson recorded the amount of time it took each participant to answer each question, this study observed how many questions remained un-answered in the first iteration of the study. The online format employed by Anderson in his research made it possible to record the exact amount of time it took each participant to respond to each task. However, the classroom environment employed in this study did not support this method. The student to researcher ratio in the classroom made it impossible to monitor each student's progress with that level of fidelity. However, since the study monitored participation, it was possible to know whether each student in the study worked continuously throughout the class period.

Very few students completed the exam tool in its entirety during the first iteration of the study. Only four students from the control group (Static) and three students from the experimental group (Dynamic) completed all twenty-four questions on the exam tool. Therefore, the study measured efficiency based on the mean progress the students from each group made on the exam tool. The study did not record completion percentage of students the classroom teacher assessed as disengaged in order to avoid lack of effort from influencing the findings.

3.6.2. Determining measurable increases in student long term memory

Research question #2 questioned whether the use of story maps increased the likelihood of transitioning ideas from short-term to long term memory. To answer this, the study used the same criterion it employed to assess knowledge extraction. However, the way that the study assessed the effectiveness and efficiency changed to reflect the different focus of the question. To assess effectiveness, the study subtracted student scores from the second iteration of the study, from their scores achieved while using the study tool in the first iteration of the study. The study then recorded the delta between the two scores and calculated the mean difference for each study group on each section of the exam tool to determine how much information the students retained between iterations of the study. To assess efficiency, the study recorded the time of completion for each student during the second iteration of the study and calculated the mean completion time for each study group. The study then compared the mean completion time to the mean difference in scores to assess whether a correlation existed between a faster response time and greater transfer of ideas to long term memory.

3.6.3. Evaluating increases in critical thought

Research question #3 sought to determine if story maps facilitate critical thought through active engagement with data as it is presented. To answer this question, the study focused on two factors: class participation and critical thought. As previously discussed, the classroom teacher observed and recorded participation for each student in the study. Students received credit for participation if they remained on task throughout the entire experiment. The study developed group participation scores based on the percentage of the population who received credit for active participation. Table 8, on page 47, defines the thresholds for each participation category. In addition to class participation, the study recorded student responses to whether they engaged with the study tool during their two week, self-study period.

Table 8 – Description of Student Participation Scores

Student Participation	Percentage
Full Participation	> 90%
Partial Participation	75% - 90%
Low Participation	50% - 74%
Poor Participation	< 50%

The study assessed critical thought using the five categories of Bloom's Taxonomy of Cognitive Learning Skills. Recall represented the students' ability to remember important facts, numbers, or events; the study judged understanding based on the students' ability to explain figures, tables, and concepts clearly outlined or provided in the lesson material; analyze reflected a consideration of cause and effect; evaluate indicated that the student provided critical or expansive comments beyond recall; and create applied to genuine or creative ideas developed by the student that could not be identified explicitly in the lesson material. The researcher graded each essay with a score from 1 to 5 based on the highest level of cognitive learning displayed in the student's written response (refer to Table 9 on page 48). The study conducted two rounds of grading to verify the researcher's initial assessment, and provide the most objective score possible. For greater detail on how the study assessed student responses, refer to the grading rubric provided in Appendix G. To assess critical thought, the study counted the total number of responses in each group that met each skill. It also identified the mean score for each essay question in each of the study groups. The study assessed both counts and averages to determine the level of critical thought generated by each tool.

Table 9 – Scoring Criteria for Essay Questions on the Exam Tool

Bloom's Cognitive Skill	Score
Recall	1
Understanding	2
Analyze	3
Evaluate	4
Create	5

Finally, the study compared the level of participation and engagement with the tool to the level of critical thought observed in student responses. To answer research question #3, the study had to determine an increase in critical thought, and whether participation and engagement with the tool were factors in higher scores. Table 10 (below) provides a description of each research question and its corresponding hypothesis.

Table 10 – Description of the Relationship Between the Study's Research Questions and Their Corresponding Hypotheses.

Research Question	Hypothesis	Null Hypothesis	Alternate Hypothesis
1. Are there measurable increases in student performance in knowledge extraction?	higher levels of performance in the experimental group (Dynamic)	no measurable difference between the two methods	higher levels of performance in the control group (Static)
2. Does the use of story maps increase the likelihood transitioning ideas from short term to long term memory?	higher levels of retention in the experimental group (Dynamic)	no measurable difference between the two methods	higher levels of retention in the control group (Static)
3. Do story maps facilitate critical thought through active participation with data as it is presented?	higher levels of critical thought in the experimental group (Dynamic) and greater levels of participation	no measurable difference between the two methods	higher levels of critical thought in the control group (Static) and greater levels of participation

Chapter 4 : Findings

Chapter 4 describes the results of the study's classroom based, student performance experiment. However, prior to proceeding with the findings, it merits re-emphasizing the scope of this study. The findings recorded in this chapter reflect the outcomes from this particular population of high school students over a two week period of research, consisting of two proctored iterations of the study and a two-week self-study opportunity. Prior to beginning the experiment, the study confirmed that the students had no prior knowledge of the Bascom Affair that would influence their responses to the questions on the exam tool. Student responses reflect their understanding of the subject based solely on the data provided in the research tool employed. Although the study raises some thought-provoking insights, the findings are not conclusive, nor are they intended to be applied universally. The study's findings reflect an initial investment into classroom based visualization studies, with the intent of inspiring additional research in the field.

The findings are reported in two categories; Quantitative findings based on the methodology reported in chapter 3, and qualitative findings based on observations from the researcher and classroom teacher during the conduct of the study iterations. Section 4.1 describes student performance in knowledge extraction tasks; Section 4.2 describes student performance in transitioning ideas to long term memory; and Section 4.3 reports the findings related to generating critical thought. The chapter closes with a discussion of qualitative findings based on observations in Section 4.4.

Statistically significant findings are identified within their tables in bold font. Significant findings at 90 percent confidence are annotated with a single asterisk "*"; significance at 95 percent confidences are annotated by two asterisks "**"; and significance at 99 percent confidence are annotated by three asterisks “***”. Unless required to denote the level of significance, the study reflects P-scores rounded to the nearest hundredth.

4.1 Classroom Based Knowledge Extraction Performance:

4.1.1. Effectiveness

When looking at each research group as a whole, the study recorded similar performance scores on the exam tool from both groups. Table 11 (below) captures the breakdown of student scores in fill-in-the-blank, true-or-false, short answer, and spatial analysis format. The control group (Static) students earned a higher average mean score on fill-in-the-blank questions, outperforming the experimental group (Dynamic) by an average of 0.5 points (6.08 to 5.58). They also earned higher marks for true-or-false (0.75 to 0.70), and spatial analysis questions (0.88 to 0.82). The experimental group recorded a higher average score on short answer questions (0.92 to 0.86). However, unpaired, two-tailed T-tests demonstrated that the differences recorded between the two groups fall within expected ranges. When considering the full population of each group, the study supports the null hypothesis that neither tool offers students a significant advantage over the other in the classroom setting.

Table 11 - Student scores by question format

Question	Control Group (Static)					Experimental Group (Dynamic)					P
Format	Min	Max	Mode	Mean	SD	Min	Max	Mode	Mean	SD	Score
Fill Blank	2	10	6	6.08	1.80	2	8	6	5.58	1.56	0.14
True or False	0	1	1	0.75	0.44	0	2	1	0.70	0.57	0.62
Short Answer	0	2	0	0.86	0.84	0	2	0	0.92	0.80	0.71
Spatial Analysis	0	6	0	0.88	1.13	0	5	0	0.82	1.07	0.78

Isolation of the gender variable produced different results. Tables 12 (below) and 13 (page 52) describe the performance of male and female students in each group. Although the study captured no statistically significant differences in the male population, it deserves mention that the male population in the experimental group (Dynamic) scored higher in all four question formats than the control group (Static). Perhaps more notable, when considered in line with the performance of female students who used the dynamic tool, is that the male population in the experimental group recorded higher scores than the full experimental population in each of the four, question formats as well.

Table 12 - Student scores amongst male students by question format

Question Format	Control Group (Static) Males					Experimental Group (Dynamic) Males					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	20	3	10	5.70	1.82	24	2	8	5.83	1.55	0.80
True or False	20	0	1	0.65	0.48	24	0	2	0.79	0.58	0.39
Short Answer	20	0	2	0.95	0.81	24	0	2	1.04	0.61	0.68
Spatial Analysis	20	0	2	1.05	0.74	24	0	5	1.13	1.30	0.81

Contrary to the findings identified so far, which failed to disprove the null hypothesis, the performance of female students yielded statistically significant results supporting the use of static tools in the classroom. Unlike their male counterparts who performed higher using the dynamic tool, females from the control group (Static) outperformed or matched their peers in the experimental group (Dynamic) in all four, question formats. Most notably, the T-test confirmed the difference between the average mean scores in the fill-in-the-blank section (6.32 to 5.35) as statistically significant with a probability score (P) of 0.03. If the null hypothesis were true, then in a random sampling of similar size, future experiments should observe a difference between the mean scores greater than the 0.97 points observed in this study in less than 3% of attempts. In this instance, the study finds evidence to support the alternate hypothesis that static maps provide female secondary school students an advantage in knowledge extraction tasks.

Table 13 - Student scores amongst female students by question format

Question Format	Control Group (Static) Females					Experimental Group (Dynamic) Females					P Score
	Count	Min	Score	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	**31**	**2**	**20**	**6.32**	**1.75**	**26**	**2**	**8**	**5.35**	**1.54**	**0.03****
True or False	31	0	1	0.81	0.40	26	0	2	0.62	0.56	0.14
Short Answer	31	0	2	0.81	0.86	26	0	2	0.81	0.92	1.00
Spatial Analysis	31	0	6	0.77	1.31	26	0	2	0.54	0.69	0.43

Note: ** represents a statistically significant difference at 95% confidence; intermediate values used in calculations: t = 2.1756, t Critical (two-tail) = 2.0040, df = 55

Isolating age also produced statistically significant results in support of the alternate hypothesis. While students in the age 14 to 15, and 16 years old groups reflected the findings of the general population, older students (17 to 18 years) in the control group (Static) outperformed their peers in the experimental group (Dynamic) by the largest margin in the study for knowledge extraction. The older students using the static tools produced an average score of 6.73 on the fill-in-the-blank questions, a full 1.90 points higher than their peers in the experimental group who earned an average of 4.83 points on the same questions. T-test confirmed the difference as statistically significant at 90 percent confidence with a P-score of 0.0508. Tables 14 through 16 on page 53 provide the breakdown of student performance by age group on knowledge extraction tasks.

Table 14 - Student scores amongst students age 14-15 by question format

Question Format	Control Group (Static) Age 14-15					Experimental Group (Dynamic) Age 14-15					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	27	2	10	6.00	1.75	34	3	8	5.71	1.31	0.46
True or False	27	0	1	0.70	0.46	34	0	2	0.65	0.54	0.70
Short Answer	27	0	2	0.67	0.81	34	0	2	0.97	0.82	0.16
Spatial Analysis	27	0	4	0.74	0.89	34	0	5	0.79	1.16	0.85

Table 15 - Student scores amongst students age 16 by question format

Question Format	Control Group (Static) Age 16					Experimental Group (Dynamic) Age 16					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	13	3	8	5.70	1.59	10	2	8	5.60	2.01	0.90
True or False	13	0	1	0.70	0.46	10	0	2	0.70	0.64	1.00
Short Answer	13	0	2	0.85	0.77	10	0	2	0.70	0.64	0.62
Spatial Analysis	13	0	3	0.62	0.92	10	0	1	0.40	0.49	0.50

Table 16 - Student scores amongst students age 17-18 by question format

Question Format	Control Group (Static) Age 17-18					Experimental Group (Dynamic) Age 17-18					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	**11**	**4**	**10**	**6.73**	**1.76**	**6**	**2**	**7**	**4.83**	**1.77**	**0.05***
True or False	11	0	1	0.91	0.29	6	0	2	1.00	0.58	0.67
Short Answer	11	0	2	1.36	0.77	6	0	2	1.00	0.82	0.38
Spatial Analysis	11	0	6	1.55	1.60	6	0	2	1.67	0.75	0.86

Note: * represents a statistically significant difference at 90% confidence; intermediate values used in calculations: t = 1.9850, t Critical (two-tail) = 1.7531, df = 15

4.1.2. Efficiency

Efficiency scores for the general population support the alternate hypothesis. On average, students in the control group (Static) responded to approximately two additional questions on the exam tool during the first iteration of the study. The T-test confirmed the statistical significance of the disparity between the groups at 90 percent confidence with a P-score of 0.06. Further isolation of the gender variable revealed that female students in the control group answered significantly more questions than those using the dynamic tool in the experimental group (Dynamic). Control group females responded to an additional three questions on the exam tool during their allotted time in the class period. The T-test confirmed the statistical significance of the efficiency gap between the two groups with a P-score of 0.02 at 95 percent confidence. Table 17 (below) identifies the efficiency scores for each population.

Table 17 - Student efficiency scores

	Control Group (Static)					Experimental Group (Dynamic)					P
Population	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	Score
Full	**51**	**7**	**24**	**15.41**	**4.76**	**50**	**6**	**23**	**13.66**	**4.54**	**0.06***
Males	20	8	23	14.85	4.44	24	6	21	14.91	4.21	0.96
Females	**31**	**7**	**24**	**15.77**	**4.92**	**26**	**6**	**23**	**12.50**	**4.52**	**0.01****
Age 14-15	27	7	24	14.63	4.72	34	6	21	13.18	4.20	0.20
Age 16	16	8	24	15.08	5.14	10	6	19	12.60	4.10	0.21
Age 17-18	11	11	23	17.73	3.49	6	11	23	18.17	4.49	0.83

Note: * represents a statistically significant difference at 90% confidence; intermediate values used in calculations: t = 1.8734, t Critical (two-tail) = 1.6604, df = 99
** represents a statistically significant difference at 95% confidence; intermediate values used in calculations: t = 2.5503, t Critical (two-tail) = 2.0040, df = 55

4.2 Transition to Long Term Memory:

4.2.1. Effectiveness

In terms of effectively transitioning ideas from short term to long term memory, the study's findings support the null hypothesis that neither tool provides students a statistically significant advantage in the classroom. In the general population, the experimental group (Dynamic) outperformed the control group (Static) in three of the question formats: Fill-in-the-blank (3.36 to 3.41), true-or-false (-0.08 to 0.10), and spatial analysis (0.04 to 0.22). Students in the control group demonstrated increased retention on the short answer format (0.57 to 0.64). However, when run through the T-tests, the differences in average scores, failed to meet the threshold for significance in any of the question formats. For a full description of average scores for each population refer to tables 18 through 23 on pages 55 to 57.

Although not statistically significant, two trends stand out when isolating gender and age. Female students from the experimental group (Dynamic) retained more information from the dynamic visualization tool than their peers using the static tool in all four question formats. They also outperformed their male counterparts in both groups and demonstrated greater transition of ideas to long term memory than either group in the general population. Similarly, 17 to 18-year-olds in the experimental group exhibited greater retention of ideas than their peers in the control group (Static). However, unlike the female population, the older student scores do not stand up when measured against the full population.

Table 18 - Difference in Scores Between Study Iterations; 0 reflects no change; negative Numbers Reflect an Increase in Student Score From Test 1 on Test 2

Question Format	Control Group (Static) Min	Max	Mode	Mean	SD	Experimental Group (Dynamic) Min	Max	Mode	Mean	SD	P Score
Fill Blank	0	8	3	3.41	1.75	-1	7	3	3.36	1.71	0.88
True or False	-1	1	0	0.10	0.57	-2	2	0	-0.08	0.72	0.16
Short Answer	-1	2	0	0.57	0.90	-1	2	1	0.64	0.93	0.70
Spatial Analysis	-3	5	0	0.22	1.11	-3	4	0	0.04	1.06	0.41

Table 19 - Difference in Scores of Male Students Between Study Iterations; Negative Numbers Reflect an Increase in Student Score From Test 1 on Test 2

Question Format	Control Group (Static) Males					Experimental Group (Dynamic) Males					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	20	0	8	3.15	2.13	24	1	7	3.63	1.41	0.38
True or False	20	-1	1	0.20	0.60	24	-1	1	-0.04	0.61	0.20
Short Answer	20	-1	2	0.55	0.81	24	0	2	0.83	0.62	0.20
Spatial Analysis	20	-1	2	0.25	0.77	24	-3	4	0.25	1.36	1.00

Table 20 - Difference in Scores of Female Students Between Study Iterations; Negative Numbers Reflect an Increase in Student Score From Test 1 on Test 2

Question Format	Control Group (Static) Females					Experimental Group (Dynamic) Females					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	31	1	6	3.58	1.43	26	-1	7	3.12	1.91	0.30
True or False	31	-1	1	0.03	0.54	26	-2	2	-0.12	0.80	0.49
Short Answer	31	-1	2	0.58	0.91	26	-1	2	0.46	1.12	0.66
Spatial Analysis	31	-3	5	0.19	1.28	26	-1	2	-0.15	0.60	0.22

Table 21 - Difference in Scores of Students Age 14-15 Between Study Iterations; Negative Numbers Reflect an Increase in Student Score From Test 1 on Test 2

Question Format	Control Group (Static) Age 14-15					Experimental Group (Dynamic) Age 14-15					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	27	0	8	3.70	2.02	34	-1	7	3.32	1.76	0.44
True or False	27	-1	1	0.11	0.57	34	-2	2	-0.15	0.77	0.15
Short Answer	27	-1	2	0.30	0.76	34	-1	2	0.62	0.97	0.17
Spatial Analysis	27	-3	2	0.15	0.97	34	-3	4	0.18	1.12	0.91

Table 22 - Difference in Scores of Students Age 16 Between Study Iterations; Negative Numbers Reflect an Increase in Student Score From Test 1 on Test 2

Question Format	Control Group (Static) Age 16					Experimental Group (Dynamic) Age 16					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	13	1	5	2.92	1.07	10	1	6	3.70	1.62	0.18
True or False	13	-1	1	0.08	0.62	10	-1	1	0.10	0.54	0.94
Short Answer	13	-1	2	0.62	0.84	10	-1	2	0.50	0.81	0.73
Spatial Analysis	13	-2	1	-0.08	0.92	10	-1	0	-0.50	0.50	0.21

Table 23 - Difference in Scores of Students Age 17-18 Between Study Iterations; Negative Numbers Reflect an Increase in Student Score From Test 1 on Test 2

Question Format	Control Group (Static) Age 17-18					Experimental Group (Dynamic) Age 17-18					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Fill Blank	11	1	6	3.27	1.54	6	1	5	3.00	1.41	0.73
True or False	11	-1	1	0.09	0.51	6	-1	1	0.00	0.58	0.75
Short Answer	11	0	2	1.18	0.83	6	0	2	1.00	0.82	0.67
Spatial Analysis	11	0	5	0.73	1.42	6	-1	2	0.17	1.07	0.41

4.2.2. Efficiency

Efficiency scores for memory retention continue the trend established from scores reported in the previous section. Like the scores related to the amount of time required for students to complete knowledge extraction tasks from the first iteration, the general population scores indicate that the control group recalled information more efficiently. The control group (Static) completed their exam tool faster than the experimental group (Dynamic), with an average score of 14.29 to 16.56 minutes. T-test confirmed the statistical significance of the finding at 90 percent confidence with a reported a P-score of 0.07.

Unlike effectiveness, when isolating the age variable, the study's findings reveal highly statistically significant information that supports the alternate hypothesis reflecting that the static tool outperformed the dynamic tool. In students age 14 to 15, the control group (Static) outperformed the experimental group (Dynamic) by 5.38 minutes. T-test confirmed the statistical significance of the efficiency score, returning a P-score of 0.0026. The findings indicate that in students age 14 to 15, the static tool offers a significant advantage to students in terms of transitioning ideas from short-term to long-term memory.

In contrast to the younger population group, older students appeared to enjoy greater success at transitioning ideas from short-term to long-term memory using the dynamic tool. Students age 17 to 18 in the experimental group (Dynamic) completed the exam tool 3.76 minutes faster, demonstrating more efficient and rapid recall of information. The T-test confirmed the large gap in performance at 90 percent confidence with a P-score of 0.06. Table 24 (page 59) provides a full description of efficiency scores based on student completion times on the second iteration of the study.

Table 24 - Student Completion Times on the Second Iteration of the Study; Min/Max Times are Rounded to the Nearest Minute

Population	Control Group (Static)					Experimental Group (Dynamic)					P Score
	Count	Min	Max	Mean	SD	Count	Min	Max	Mean	SD	
Full	**51**	**7**	**26**	**14.29**	**5.07**	**50**	**7**	**60**	**16.56**	**7.26**	**0.07***
Males	20	8	26	14.45	5.45	24	7	24	15.88	3.75	0.31
Females	31	7	25	14.19	4.81	26	10	60	17.19	9.36	0.12
Age 14-15	**27**	**8**	**19**	**12.00**	**3.22**	**34**	**7**	**60**	**17.38**	**8.40**	**0.0026*****
Age 16	16	7	25	14.15	5.28	10	10	19	13.90	2.70	0.95
Age 17-18	**11**	**15**	**26**	**20.09**	**3.80**	**6**	**13**	**23**	**16.33**	**3.35**	**0.06***

Note: * represents statistically significant differences at 90%; intermediate values used in calculations for the full population: t = -1.8032, t Critical (two-tail) = 1.6604, df = 99; ; intermediate values used in calculations for the age 17 - 18 population: t = 1.9064, t Critical (two-tail) = 1.7531, df = 15
*** represents a very statistically significant difference at 99% confidence - Intermediate values used in calculations: t = -3.0980, t Critical (two-tail) = 2.6618 df = 59

4.3 Assessing Critical Thought:

4.3.1. Effectiveness

The study primarily evaluated critical thought based on student responses to the exam tool's four essay questions in each of the two study iterations. Response rates to the essay questions increased for both research groups between the first and second iteration. As demonstrated by Table 25 (below), the control group (Static) saw a 29% increase and the experimental group (Dynamic) more than doubled their rate of response from 30% on the first test, to 76% on test two.

Table 25 - Percentage of Students That Attempted the Essay Questions on the Exam Tool

	1st Test	2nd Test
Control Group (Static)	49%	78%
Experimental Group (Dynamic)	30%	76%

Based on mean scores as depicted in table 26 on page 57, the control group (Static) outperformed the experimental group (Dynamic) on three of the four essay questions during the first iteration. On essay question #1, which asked the students to describe where the Bascom Affair took place, the control group recorded an average score of 1.20. The experimental group scored an average of 0.52 on the same question using the dynamic tool. When assessed using through the T-test, the difference in scores received a P-score of 0.02 at 95 percent confidence.

The experimental group (Dynamic) improved their performance on the second iteration as their response rate improved. The control group (Static) continued to score higher on the first essay question, but the difference between the scores no longer registered statistical significance. As illustrated in Table 26 on page 61, the experimental group doubled their mean score from 0.52 on the first exam, to 1.04 on exam two. Meanwhile, despite an increased response rate in the control group as well, their mean score only improved to 1.27, a difference of 0.07 hundredths of a point.

Both research groups experienced statistically significant improvement between the two iterations, as demonstrated in Table 27 on page 61. The control group (Static) improved from 0.82 to 1.39 (P-score of 0.0538) on question 2; from 0.27 to 0.90 on question 3 (P-score of 0.0059); and from 0.29 to 0.88 (P-score of 0.02) on question 4. The experimental group (Dynamic) saw the largest improvement, going from a 0.52 to 1.04 on question 1(P-score of 0.03); a 0.040 to a 1.58 on question 2 (P-score of 0.0001); a 0.36 to a 0.86 on question 3(P-score of 0.04), and from 0.18 to 1.12 on essay question 4 (P-score of 0.0004) on the second iteration. Universal improvement in mean scores by both research groups continues to support the null hypothesis. Following the second study iteration, neither group posted scores significantly greater than the other.

Table 26 - Student Performance on Exam Tool Essay Questions

Question Number		Control Group (Static) Min	Max	Mean	SD	Experimental Group (Dynamic) Min	Max	Mean	SD	P Score
1st Test	**Essay #1**	**0**	**5**	**1.20**	**1.69**	**0**	**5**	**0.52**	**1.04**	**0.02****
	Essay #2	0	5	0.82	1.45	0	5	0.40	1.10	0.10
	Essay #3	0	4	0.27	0.84	0	5	0.36	1.11	0.65
	Essay #4	0	4	0.29	0.89	0	3	0.18	0.71	0.50
2nd Test	Essay #1	0	5	1.27	1.60	0	4	1.04	1.30	0.43
	Essay #2	0	4	1.39	1.51	0	5	1.58	1.73	0.56
	Essay #3	0	4	0.90	1.36	0	5	0.86	1.23	0.88
	Essay #4	0	5	0.88	1.54	0	5	1.12	1.68	0.46

Note: ** represents a statistically significant difference at 95% confidence; intermediate values used in calculations: t = 2.3870, t Critical (two-tail) = 1.9842, df = 99

Table 27 - Difference in Average Scores Between Study Iterations

	Question #	1st Test	2nd Test	Change	P-Score
Control Group (Static) (N=51)	Essay #1	1.20	1.27	+0.07	0.83
	Essay #2	**0.82**	**1.39**	**+0.57**	**0.05***
	Essay #3	**0.27**	**0.90**	**+0.63**	**0.0059*****
	Essay #4	**0.29**	**0.88**	**+0.59**	**0.02****
Experimental Group (Dynamic) (N=50)	**Essay #1**	**0.52**	**1.04**	**+0.52**	**0.03****
	Essay #2	**0.40**	**1.58**	**+1.18**	**0.0001*****
	Essay #3	**0.36**	**0.86**	**+0.50**	**0.04****
	Essay #4	**0.18**	**1.12**	**+0.94**	**0.0004*****

Note: **Control Group:** * represents a statistically significant difference at 90% confidence; intermediate values used in calculations: t = -1.9204, t Critical (two-tail) = 1.6602, df = 100
** represents a statistically significant difference at 95% confidence; intermediate values used in calculations: t = -2.3346, t Critical (two-tail) = 1.9840, df = 100
*** represents a statistically significant difference at 99% confidence; intermediate values used in calculations: t = -2.7718, t Critical (two-tail) = 2.6259, df = 100
Experimental Group: ** represent statistically significant differences at 95% confidence; intermediate values used in calculations for essay #1: t = -2.1879, t Critical (two-tail) = 1.9845, df = 98; intermediate values used in calculations for essay #3: t = -2.1103, t Critical (two-tail) = 1.9845, df = 98
*** represent statistically significant differences at 99% confidence; intermediate values used in calculations for essay #2: t = -4.0287, t Critical (two-tail) = 2.6269, df = 98; intermediate values used in calculations for essay #4: t = -3.6041, t Critical (two-tail) = 2.6269; df = 98

Assessing student responses by count provided the study additional insight. Table 28 (below) depicts the number of responses recorded from each research group organized by the highest level of cognitive thought exhibited in the student's response. The study considered responses recorded as analyze, evaluate, or create as higher forms of cognitive thought, while simple recall and understanding reflected basic knowledge of the subject. Looking at responses by count allowed the study to negate the influence of missing responses by determining percentages derived from actual answers provided by the students. By count, students in the control group (Static) outperformed the experimental group (Dynamic) in both study iterations, although the margin decreased between the first and second iteration of the study.

Table 28 - Student Performance By Count Reflecting Bloom's Hierarchy of Cognitive Thought

Question Number		Control Group(Static)					Experimental Group (Dynamic)				
		Recall	Understanding	Analyze	Evaluate	Create	Recall	Understanding	Analyze	Evaluate	Create
1st Test	Essay #1	4	7	0	7	3	7	5	0	1	1
	Essay #2	7	2	4	1	3	1	2	2	1	1
	Essay #3	2	1	2	1	0	1	2	1	0	2
	Essay #4	2	0	3	1	0	0	0	3	0	0
	Total	**15**	**10**	**9**	**10**	**6**	**9**	**9**	**6**	**2**	**4**
2nd Test	Essay #1	16	6	0	3	5	17	4	1	6	0
	Essay #2	8	3	11	6	0	8	2	8	7	3
	Essay #3	4	3	8	3	0	10	7	2	2	1
	Essay #4	3	2	4	4	2	7	0	8	0	5
	Total	**31**	**14**	**23**	**16**	**7**	**42**	**11**	**19**	**15**	**9**

On the first exam, students from the control group (Static) answered 25/50 (50%) questions that the study scored as higher cognitive thought. The experimental group (Dynamic) recorded 12/30 (40%) higher level responses on the same test. Similarly, on the second exam, the control group recorded 46/91 (51%) higher level responses while the experimental group earned 43/96 (45%). These findings support the alternate hypothesis, indicating that the static tool provided students an increased advantage in the classroom, and generated increased levels of critical thought in the general student population.

Isolation of the gender variable continued to yield significant findings. Although differences in mean scores across the male population of students failed to yield statistically significant findings demonstrating a benefit from either tool, males in the experimental group (Dynamic) continued to post higher average scores. As indicated in Table 29 (below), the experimental population outperformed the control group (Static) on three out of four essay questions in both iterations of the study. Both groups saw improvement between their scores on the first test and the second test, but not to the same level witnessed in the general population. Table 30 (on page 64) identifies significant findings in essay question 1 for the control group, and question 2 for the experimental group.

Table 29- Male Student Performance on Exam Tool Essay Questions

Question Number		Control Group Males (Static) (N=20)				Experimental Group (Dynamic) Males (N=24)				P
		Min	Max	Mean	SD	Min	Max	Mean	SD	Score
1st Test	Essay #1	0	5	0.75	1.51	0	5	0.75	1.30	1.00
	Essay #2	0	5	1.00	1.70	0	5	0.67	1.43	0.49
	Essay #3	0	3	0.20	0.68	0	5	0.63	1.50	0.24
	Essay #4	0	3	0.15	0.65	0	3	0.38	0.99	0.38
2nd Test	Essay #1	0	5	1.65	1.93	0	4	1.21	1.55	0.41
	Essay #2	0	4	1.55	1.53	0	5	1.75	1.83	0.70
	Essay #3	0	4	0.80	1.25	0	4	0.96	1.14	0.66
	Essay #4	0	4	0.65	1.31	0	5	0.83	1.40	0.67

By count, the study's findings continue to reinforce the null hypothesis amongst the male population. In the first iteration, males in the control group (Static) received credit for 9/15 (60%) responses matching higher level cognitive values. The experimental group (Dynamic) earned 12/21(57%) higher level responses. Greater parody occurred on the second exam where the control group scored 18/36 (50%) higher level scores to the experimental group's 23/45 (51%). Male student scores by count are captured below in Table 31.

Table 30 - Difference in Average Scores for Male Student Between Study Iterations

	Question #	1st Test	2nd Test	Change	P-Score
Control Group (Static) (N=20)	Essay #1	0.75	1.65	+0.90	0.12
	Essay #2	1.00	1.55	+0.55	0.29
	Essay #3	**0.20**	**0.80**	**+0.60**	**0.07***
	Essay #4	0.15	0.65	+0.50	0.14
Experimental Group (Dynamic) (N=24)	Essay #1	0.75	1.21	+0.46	0.27
	Essay #2	**0.67**	**1.75**	**+1.08**	**0.03****
	Essay #3	0.63	0.96	+0.33	0.39
	Essay #4	0.38	0.83	+0.45	0.21

Note: **Control Group:** * represents a statistically significant difference at 90% confidence; intermediate values used in calculations: t = -1.8401, t Critical (two-tail) = 1.6859, df = 38
Experimental Group: ** represent a statistically significant difference at 95% confidence; intermediate values used in calculations: t = -2.2338, t Critical (two-tail) = 2.0129, df = 46

Table 31 - Male Student Performance By Count Reflecting Bloom's Hierarchy of Cognitive Thought

Question Number		Control Group (Static) Males					Experimental Group (Dynamic) Males				
		Recall	Understanding	Analyze	Evaluate	Create	Recall	Understanding	Analyze	Evaluate	Create
1st Test	Essay #1	3	1	0	0	2	5	2	0	1	1
	Essay #2	1	0	3	0	2	1	0	2	1	1
	Essay #3	1	0	1	0	0	0	1	1	0	2
	Essay #4	0	0	1	0	0	0	0	3	0	0
	Total	**5**	**1**	**5**	**0**	**4**	**6**	**3**	**6**	**2**	**4**
2nd Test	Essay #1	5	2	0	1	4	5	2	0	5	0
	Essay #2	3	2	4	3	0	2	0	6	3	2
	Essay #3	2	2	2	1	0	4	6	1	1	0
	Essay #4	2	0	1	2	0	3	0	4	0	1
	Total	**12**	**6**	**7**	**7**	**4**	**14**	**8**	**11**	**9**	**3**

Table 32 on page 65 portrays the scores from the female population of students on the essay questions from the exam tool. On the first essay question, females in the control group

(Static) recorded an average score of 1.48. The experimental group (Dynamic) earned an average score of 0.31. The T-test returned a P-score of 0.0021, indicating strong support for the alternate hypothesis. In fact, the disparity between the recorded average scores of female students in both groups during the first iteration of the study was so large, that it influenced the statistically significant finding in the general population on the same question.

Table 32- Female Student Performance on Exam Tool Essay Questions

Question Number		Control Group (Static) Females (N=31)				Experimental Group (Dynamic) Females (N=26)				P
		Min	Max	Mean	SD	Min	Max	Mean	Std_Dev	Score
1st Test	**Essay #1**	**0**	**5**	**1.48**	**1.74**	**0**	**2**	**0.31**	**0.67**	**0.002*****
	Essay #2	**0**	**5**	**0.71**	**1.25**	**0**	**2**	**0.15**	**0.53**	**0.04****
	Essay #3	0	4	0.32	0.93	0	2	0.12	0.42	0.32
	Essay #4	0	4	0.39	1.01	0	0	0	0	N/A
2nd Test	Essay #1	0	5	1.03	1.28	0	4	0.88	0.97	0.63
	Essay #2	0	4	1.29	1.49	0	5	1.42	1.62	0.75
	Essay #3	0	4	0.97	1.43	0	5	0.77	1.31	0.59
	Essay #4	0	5	1.03	1.66	0	5	1.38	1.86	0.46

Note: ** represent a statistically significant difference at 95% confidence; intermediate values used in calculations: t = -2.0756, t Critical (two-tail) = 2.0040, df = 55
*** represent statistically significant differences at 99% confidence; intermediate values used in calculations: t = 3.1968, t Critical (two-tail) = 2.6682, df = 55

The findings also indicate that contrary to the relative parody recorded between the two exams in the male population, female students demonstrated statistically significant increases in performance at a much greater rate in the experimental group (Dynamic). (Table 33 on page 66 provides a full description of difference in scores recorded by female students in each research group) During the second iteration, the experimental group recorded highly statistically significant increases in score on every essay question, confirmed through T-tests. In contrast, the average scores in the control group (Static) mirrored changes observed in the male population and remained statistically consistent.

Table 33 - Difference in Average Scores for Female Student Between Study Iterations

	Question #	1st Test	2nd Test	Change	P-Score
Control Group (Static) (N=31)	Essay #1	1.48	1.03	-0.45	0.25
	Essay #2	0.71	1.29	+0.58	0.10
	Essay #3	**0.32**	**0.97**	**+0.65**	**0.04****
	Essay #4	**0.39**	**1.03**	**+0.64**	**0.07***
Experimental Group (Dynamic) (N=26)	**Essay #1**	**0.31**	**0.88**	**+0.57**	**0.02****
	Essay #2	**0.15**	**1.42**	**+1.27**	**0.0004*****
	Essay #3	**0.12**	**0.77**	**+0.65**	**0.02****
	Essay #4	0	1.38	+1.38	N/A

Note: **Control Group:** * represents a statistically significant difference at 90% confidence; intermediate values used in calculations: t = -1.8242, t Critical (two-tail) = 1.6706, df = 60
** represents a statistically significant difference at 95% confidence; intermediate values used in calculations: t = -2.0769, t Critical (two-tail) = 2.0003, df = 60
Experimental Group: ** represent statistically significant differences at 95% confidence; intermediate values used in calculations for essay #1: t = -2.4450, t Critical (two-tail) = 2.0086, df = 50; intermediate values used in calculations for essay #3: t = -2.3749, t Critical (two-tail) = 2.0086, df = 50
*** represents a statistically significant difference at 99% confidence; intermediate values used in calculations: t = -3.7184, t Critical (two-tail) = 2.6778, df = 50

Observations on female performance on the exam tool's essay questions by count also reinforce the alternate hypothesis (Table 34 on page 67). The control group (Static) recorded 16/35 (46%) responses that matched the criteria for higher level cognitive function during the first iteration. The experimental group (Dynamic) failed to provide a single response that the study measured above basic understanding of the topic. Despite significant improvement in the experimental population during the second iteration, they still only provided 20/53 (38%) responses that met higher level parameters. The control group received credit for 28/55 (51%) of their responses.

Table 34 - Female Student Performance By Count Reflecting Bloom's Hierarchy of Cognitive Thought

Question Number		Control Group (Static) Females					Experimental Group (Dynamic) Females				
		Recall	Understanding	Analyze	Evaluate	Create	Recall	Understanding	Analyze	Evaluate	Create
1st Test	Essay #1	1	6	0	7	1	2	3	0	0	0
	Essay #2	6	2	1	1	1	0	2	0	0	0
	Essay #3	1	1	1	1	0	1	1	0	0	0
	Essay #4	2	0	2	1	0	0	0	0	0	0
	Total	**10**	**9**	**4**	**10**	**2**	**3**	**6**	**0**	**0**	**0**
2nd Test	Essay #1	11	4	0	2	1	12	2	1	1	0
	Essay #2	5	1	7	3	0	6	2	2	4	1
	Essay #3	2	1	6	2	0	6	1	1	1	1
	Essay #4	1	2	3	2	2	4	0	4	0	4
	Total	**19**	**8**	**16**	**9**	**3**	**28**	**5**	**8**	**6**	**6**

The study also identified several significant findings through isolation of the age variable. Despite having the largest sub-population group in the study, students in the experimental group (Dynamic) for the 14 to 15-year-old age category produced the lowest critical thought scores in the study on the first exam. During the first iteration, they only provided responses to the first two essay questions. The control group (Static) outperformed them on the first essay question by an average score of 1.44 to 0.26, and the second essay question by a score of 0.67 to 0.15. Through T-tests, the study confirmed the statistical significance of the difference in mean scores, producing P-scores of 0.0007 and 0.03 respectively.

However, as depicted in Table 35 and Table 36 on page 68, the experimental group (Dynamic) demonstrated extremely statistically significant improvement between the two iterations. Although none of the average differences in scores between the research groups met the threshold for significance in the second iteration, the experimental group outperformed the control group (Static) in three of the four questions by relatively large margins; 1.56 to 0.96 on question 2; 1.31 to 0.41 on question 3; and 1.70 to 0.52 on question 4. T-test ran against scores for essay questions 1 and 2 both returned P-scores of 0.0001 confirming the significance of the change observed in performance between the two iterations of the study.

Table 35 - Performance of Students Age 14-15 on the Exam Tool Essay Questions

Question Number		Control Group (Static) Age 14-15 (N=27)				Experimental Group (Dynamic) Age 14-15 (N=34)				P
		Min	Max	Mean	SD	Min	Max	Mean	SD	Score
1st Test	**Essay #1**	**0**	**5**	**1.44**	**1.81**	**0**	**2**	**0.26**	**0.61**	**0.0009*****
	Essay #2	**0**	**5**	**0.67**	**1.22**	**0**	**3**	**0.15**	**0.60**	**0.04****
	Essay #3	0	2	0.11	0.42	0	0	0	0	N/A
	Essay #4	0	3	0.30	0.81	0	0	0	0	N/A
2nd Test	Essay #1	0	5	1.19	1.52	0	4	1.09	0.75	0.74
	Essay #2	0	4	0.96	1.55	0	5	1.56	1.75	0.17
	Essay #3	0	4	0.41	1.55	0	5	0.85	1.31	0.23
	Essay #4	0	4	0.52	1.31	0	5	1.00	1.70	0.23

Note: ** represents a statistically significant difference at 95% confidence; intermediate values used in calculations: t = 2.1417, t Critical (two-tail) = 2.0010, df = 59
*** represents a statistically significant difference at 99% confidence; intermediate values used in calculations: t = 3.4930, t Critical (two-tail) = 2.6618, df = 59

Table 36 - Difference in Average Scores Between Study Iterations for Students Age 14-15

	Question #	1st Test	2nd Test	Change	P-Score
Control Group (Static) (N=27)	Essay #1	1.44	1.19	-0.25	0.58
	Essay #2	0.67	0.96	+0.29	0.45
	Essay #3	0.11	0.41	+0.30	0.33
	Essay #4	0.30	0.52	+0.22	0.46
Experimental Group (Dynamic) (N=34)	**Essay #1**	**0.26**	**1.09**	**+0.83**	**0.0001*****
	Essay #2	**0.15**	**1.56**	**+1.41**	**0.0001*****
	Essay #3	0	0.85	+0.85	N/A
	Essay #4	0	1.00	+1.00	N/A

Note: *** represent statistically significant differences at 99% confidence; intermediate values used in calculations for essay #1: t = -3.0967, t Critical (two-tail) = 2.6524, df = 66; intermediate values used in calculations for essay #2: t = -4.3785, t Critical (two-tail) = 2.6524, df = 66

Assessment of student responses by count for the 14-15-year-old age category provided additional insight reflected in Table 37 on page 69. As expected based on the number of responses during the first iteration of the study, the control group (Static) outperformed the experimental group (Dynamic). On the first exam, the control group recorded 12/28 (43%) responses meeting the threshold for higher level cognitive function. The experimental group recorded 1/8 (13%) responses. However, on the second exam, the control group only recorded 13/40 (33%) responses meeting the criteria for higher level thought. The experimental group provided 29/61 (48%) higher level responses, providing evidence in support of the hypothesis that the dynamic study tool leads to increased levels of critical thought in students.

Table 37 - Performance of Students Age 14-15 By Count Reflecting Bloom's Hierarchy of Cognitive Thought

Question Number		Control Group (Static) Age 14-15					Experimental Group (Dynamic) Age 14-15				
		Recall	Understanding	Analyze	Evaluate	Create	Recall	Understanding	Analyze	Evaluate	Create
1st Test	Essay #1	3	3	0	5	2	3	3	0	0	0
	Essay #2	5	1	2	0	1	0	1	1	0	0
	Essay #3	1	1	0	0	0	0	0	0	0	0
	Essay #4	2	0	2	0	0	0	0	0	0	0
	Total	**11**	**5**	**4**	**5**	**3**	**3**	**4**	**1**	**0**	**0**
2nd Test	Essay #1	10	2	0	2	2	10	2	1	5	0
	Essay #2	6	3	2	2	0	4	2	5	5	2
	Essay #3	2	1	1	1	0	4	5	2	1	1
	Essay #4	2	1	2	1	0	5	0	3	0	4
	Total	**20**	**7**	**5**	**6**	**2**	**23**	**9**	**11**	**11**	**7**

The study observed the opposite trend amongst 16 year old students, as reflected in Table 38 on page 70. Students in the experimental group (Dynamic) of the 16 year old population earned higher mean scores on all four essay questions in the first iteration of the study. In the second iteration, the control group (Static) earned higher scores on three of the four questions. Based on the findings reported in Table 39 on page 71, neither group experienced a significant change in scores between iterations suggesting that the variation observed likely occurred by chance. When the study implemented T-tests, the resulting P-scores supported the null hypothesis. Based on the recorded scores, the study lacks sufficient evidence to support either tool offering students in the 16-year-old category a significant advantage over the other.

Table 38 - Performance of Students Age 16 on the Exam Tool Essay Questions

Question Number		Control Group (Static) Age 16 (N=13)				Experimental Group (Dynamic) Age 16 (N=10)				P
		Min	Max	Mean	SD	Min	Max	Mean	SD	Score
1st Test	Essay #1	0	5	1.08	1.64	0	5	1.10	1.76	0.98
	Essay #2	0	4	1.00	1.41	0	5	1.20	1.89	0.77
	Essay #3	0	4	0.77	1.42	0	5	1.60	1.96	0.25
	Essay #4	0	4	0.54	1.28	0	3	0.90	1.38	0.52
2nd Test	Essay #1	0	5	1.00	1.36	0	2	0.80	0.75	0.68
	Essay #2	0	4	1.54	1.55	0	4	1.40	1.36	0.82
	Essay #3	0	4	1.38	1.55	0	4	1.00	1.18	0.53
	Essay #4	0	4	0.77	1.31	0	3	1.20	1.47	0.47

Score assessments by count (Table 40 on page 69) reflect the same variation observed by studying the mean scores of each research group. In the first iteration, the control group (Static) earned credit for 9/15 (60%) higher level responses. The experimental group (Dynamic) turned in 11/15 (73%) responses, earning the highest percentage of responses reflecting higher cognitive function of any sub-population in the study in either iteration. During the second iteration, the control group (Static) increased their performance level. They responded with 19/30 (63%) responses matching the study’s criteria for higher level thought. The experimental group’s performance decreased as the study recorded 8/23 (35%) upper-level responses from them on the second exam.

Table 39 - Difference in Average Scores Between Study Iterations for Students Age 16

	Question #	1st Test	2nd Test	Change	P-Score
Control Group (Static) (N=13)	Essay #1	1.08	1.00	-0.08	0.89
	Essay #2	1.00	1.54	+0.54	0.36
	Essay #3	0.77	1.38	+0.61	0.31
	Essay #4	0.54	0.77	+0.23	0.65
Experimental Group (Dynamic) (N=10)	Essay #1	1.10	0.80	-0.30	0.63
	Essay #2	1.20	1.40	+0.20	0.79
	Essay #3	1.60	1.00	-0.60	0.42
	Essay #4	0.90	1.20	+0.30	0.64

Table 40 - Performance of Students Age 16 By Count Reflecting Bloom's Hierarchy of Cognitive Thought

Question Number		Control Group (Static) Age 16					Experimental Group (Dynamic) Age 16				
		Recall	Understanding	Analyze	Evaluate	Create	Recall	Understanding	Analyze	Evaluate	Create
1st Test	Essay #1	1	2	0	1	1	2	0	0	1	1
	Essay #2	1	1	2	1	0	0	0	1	1	1
	Essay #3	0	0	2	1	0	1	1	1	0	2
	Essay #4	0	0	1	1	0	0	0	3	0	0
	Total	**2**	**3**	**5**	**4**	**1**	**3**	**1**	**5**	**2**	**4**
2nd Test	Essay #1	4	2	0	0	1	4	2	0	0	0
	Essay #2	1	0	5	1	0	4	0	2	1	0
	Essay #3	0	1	4	1	0	4	1	0	1	0
	Essay #4	1	2	3	4	0	0	0	4	0	0
	Total	**6**	**5**	**12**	**6**	**1**	**12**	**3**	**6**	**2**	**0**

The findings reported in Table 41, and Table 42 (page 72) indicate that neither tool provided a significant advantage to students in the 17 to 18 age group. Although the experimental group (Dynamic) outperformed the control group (Static) on two of the three questions that they responded to during the first iteration of the study, the control group outperformed the experimental group during the second iteration on all four questions. T-tests indicate a lack of significant evidence to support a significant difference between the mean scores of each group in either iteration, supporting the null hypothesis.

Table 41 - Performance of Students Age 17-18 on the Exam Tool Essay Questions

Question Number		Control Group (Static) Age 17-18 (N=11)				Experimental Group (Dynamic) Age 17-18 (N=6)				P
		Min	Max	Mean	SD	Min	Max	Mean	SD	Score
1st Test	Essay #1	0	4	0.73	1.29	0	2	1.00	0.82	0.65
	Essay #2	0	5	1.00	1.91	0	2	0.50	0.76	0.55
	Essay #3	0	1	0.09	0.29	0	2	0.33	0.75	0.35
	Essay #4	0	0	0	0	0	0	0	0	N/A
2nd Test	Essay #1	0	5	1.82	1.90	0	4	1.17	1.34	0.47
	Essay #2	0	4	2.27	1.60	0	5	2.00	2.08	0.77
	Essay #3	0	4	1.55	1.44	0	2	0.67	0.75	0.19
	Essay #4	0	5	1.91	2.15	0	5	1.67	1.80	0.82

Table 42 - Difference in Average Scores Between Study Iterations for Students Age 17-18

	Question #	1st Test	2nd Test	Change	P-Score
Control Group (Static) (N=11)	Essay #1	0.73	1.82	+1.09	0.13
	Essay #2	1.00	2.27	+1.27	0.11
	Essay #3	**0.09**	**1.55**	**+1.46**	**0.005*** **
	Essay #4	0	1.91	+1.91	N/A
Experimental Group (Dynamic) (N=6)	Essay #1	1.00	1.17	+0.17	0.80
	Essay #2	0.50	2.00	+1.50	0.13
	Essay #3	0.33	0.67	+0.34	0.45
	Essay #4	0	1.67	+1.67	N/A

Note: *** represents a statistically significant difference at 99% confidence; intermediate values used in calculations: t = -3.1379, t Critical (two-tail) = 2.8453, df = 20

Unlike the findings based on mean scores, the study found that the assessment by count indicated support for the alternate hypothesis. Although the experimental group (Dynamic) earned higher mean scores in the first iteration, they failed to earn a single response registering higher level thought while the control group (Static) earned 3/7 (42%) responses that demonstrated advance cognitive function. The control group outperformed the experimental group in the second iteration as well by recording 19/27 (70%) higher level responses. The experimental population achieved 6/14 (43%) responses on the second exam that demonstrated higher cognitive function. See table 43 below for a full description of student scores by count in the 17-18 age group.

Table 43 - Performance of Students Age 17-18 By Count Reflecting Bloom's Hierarchy of Cognitive Thought

Question Number		Control Group (Static) Age 17-18					Experimental Group (Dynamic) Age 17-18				
		Recall	Understanding	Analyze	Evaluate	Create	Recall	Understanding	Analyze	Evaluate	Create
1st Test	Essay #1	0	2	0	1	0	2	2	0	0	0
	Essay #2	1	0	0	0	2	1	1	0	0	0
	Essay #3	1	0	0	0	0	0	1	0	0	0
	Essay #4	0	0	0	0	0	0	0	0	0	0
	Total	**2**	**2**	**0**	**1**	**2**	**3**	**4**	**0**	**0**	**0**
2nd Test	Essay #1	2	2	0	1	2	3	0	0	1	0
	Essay #2	1	0	4	3	0	0	0	1	1	1
	Essay #3	2	1	3	1	0	2	1	0	0	0
	Essay #4	0	0	1	2	2	2	0	1	0	1
	Total	**5**	**3**	**8**	**7**	**4**	**7**	**1**	**2**	**2**	**2**

4.3.2. Participation and Engagement

Both groups actively participated in the study. Table 44 on page 74 describes the level of participation for each group during the first iteration of the study, as recorded by the classroom teacher. The experimental group (Dynamic) received credit for full participation (100%) based on their actions while the control group (Static) earned credit for partial participation (90%). Further description of student participation is captured in qualitative findings in the following sub-section of chapter 4.

The study observed low student engagement with the tool outside of the classroom in both groups. Contrary to the hypothesis that the dynamic tool would generate student interest and lead to additional engagement with the tool itself, the study found evidence that the students in the control group (Static) accessed the study tool at a higher rate, and more frequently during the two-week self-study period. The experimental group (Dynamic) students did engage with the tool for longer periods of time when they accessed it. However, due to the frequency with which the control group returned to the tool, they spent more time with their tool than the experimental group students did between iterations.

Table 44 - Student Class Participation and Engagement with the Research Tool

Study Group	Class Participation	Individual Access	Mean Access Frequency	Mean Access Hours	Access Method
Control (Static)	90%	20%	3.73	1.27	10 x Packet
Experimental (Dynamic)	100%	14%	2.14	1.43	6 x Computer 1 x Phone

In both groups, instruction to review the study tool played the primary factor that led students to study the materials between iterations. As reflected in Table 45 on page 75, only 6% of students in the control group (Static), and 4% of students in the experimental group (Dynamic) reported interest in the topic or tool itself as their primary reason for study. In fact, 66% of students in the experimental group actually indicated a complete lack of interest as the primary reason that they declined to participate in the two-week self-study period. The study found that a majority of the control group students neglected to participate based on a lack of time due to other course work requirements, and extra-curricular activities such as after-school sports and clubs.

Table 45 - Student Motivation for Level of Engagement with the Research Tool During the Self Study Period

Control Group (Static)		Experimental Group (Dynamic)	
Motivation	Percentage	Motivation	Percentage
Map/Topic Interest	6%	Map/Topic Interest	4%
Easy Access	2%	Easy Access	4%
Instructed to Study	12%	Instructed to Study	6%
No Time	41%	No Time	20%
No Interest	39%	No Interest	66%

The study found that students in both groups who accessed the study materials witnessed an increase in their critical thought scores (Table 46 below). However, as previously discussed, most students increased their score between iterations. The study lacks sufficient data to identify access to the tool as the primary reason for this change.

Table 46 - Correlation Between Class Participation and Student Engagement with the Study Tool, and Student Performance in Critical Thought

	ID#	Participation in Class	Motivation for Engagement	Response to #11 (1st/2nd Test)	1st Test Score (Essays)	2nd Test Score (Essays)	Change
Control	13589	Yes	Topic Interest	T/T	9 (4/5/0/0)	16 (4/3/4/5)	+ 5
	13591	Yes	Topic Interest	T/T	0	1 (0/1/0/0)	+ 1
	13593	Yes	Instructed to	T/T	0	4 (0/4/0/0)	+ 4
	13605	Yes	Instructed to	T/T	0	10 (1/3/2/4)	+ 10
	13611	Yes	Easy Access	T/T	0	9 (2/3/1/3)	+ 9
	13765	Yes	Instructed to	T/T	4 (1/3/0/0)	4 (1/2/1/0)	--
	13771	Yes	Topic Interest	T/F	1 (1/0/0/0)	0	-1
	13781	Yes	Instructed to	T/T	2 (2/0/0/0)	8 (0/3/3/2)	+ 8
	13785	Yes	Instructed to	T/T	7 (2/1/1/3)	7 (1/3/0/3)	--
	13805	Yes	Instructed to	F/T	4 (4/0/0/0)	1 (1/0/0/0)	- 3
Experimental	13627	Yes	Easy Access	T/T	0	2 (1/1/0/0)	+ 2
	13631	Yes	Map Interest	T/T	0	0	--
	13639	Yes	Topic Interest	T/T	0	10 (4/3/2/1)	+ 10
	13659	Yes	Instructed to	T/T	0	16 (2/4/5/5)	+ 16
	13661	Yes	Instructed to	T/T	0	1 (1/0/0/0)	+ 1
	13667	Yes	Instructed to	T/T	0	2 (1/0/0/1)	+ 2
	13689	Yes	Easy Access	T/T	0	14 (4/3/2/5)	+ 14

4.4 Qualitative Research Observations

4.4.1. Student Engagement

The study observed increased levels of distraction in the control group (Static), not present in the iterations conducted with the experimental group (Dynamic). Although most students remained on task, approximately 10 to 15 minutes into the class period, individuals began losing focus due to frustration incurred while mining for data in the packet to answer a question on the exam tool. As a result, students in the control group exhibited a higher likelihood to work in pairs, or small groups at times as they turned to other students at their table to help them make progress. This behavior was completely absent from the experimental group. Students using the dynamic tool remained completely engaged and focused on the computer in front of them for the duration of the experiment. Over the course of the three class periods that comprised the experimental population, students remained on task and did not engage with other students.

4.4.2. Student Interaction with the Study Tool

Due to their familiarity with the format, students from the control group (Static) experienced little difficulty working with their static tool set. As supported by their efficiency scores and essay attempts from the first iteration of the study, the students worked through the packet at a much faster pace than their peers in the experimental population (Dynamic). They also demonstrated a greater likelihood to create and implement measurement tools to use with their maps for the purpose of judging distance on the spatial analysis questions. Whereas most students from the experimental group judged distance primarily by estimation, students in the control group frequently made tick marks on pieces of scratch paper or reached for a ruler.

Students in the experimental group (Dynamic) exhibited far more interest in the tool itself, possibly to the point of distraction. The study had to remind the experimental group not to linger on questions they couldn't answer, and to continue to make forward progress through the exam tool. As previously noted, they worked completely silently throughout the period. Although the study presented the same material in both tools in the same order, students using the story map went through the data in a less linear manner than those using the paper tool. They tended to move freely between tabs and manipulate the maps and pop outs according to the question they were trying to answer from the exam tool. The study also observed greater focus on the maps themselves in the experimental group, whereas the control group (Static) focused more heavily on the narrative.

Although the study threw out the student's responses when developing the mean score for the experimental group (Dynamic), it recorded an instance of web browser use to search for additional information on the topic. The study purposely excluded hyperlinks from the dynamic tool in order to maintain parody with the static tool. However, they provide a powerful resource to teachers in the classroom. The ability to link sources directly into the lesson content increases the likelihood that students will follow them. Although students from the control group (Static) could have used their phone at any point to conduct similar searches, the study did not record a single instance.

4.4.3. Financial Considerations

The study incurred approximately $500.00 in costs to develop the static tool for the control group (Static) students. Because the maps required color, ink for printing accounted for the majority of the cost. The study opted to use a home printer to create the static tools to save money on printing. Had the booklets been prepared professionally, it would have costs $550.00

without binding materials. The study produced 60 packets for the control group, enough for each student plus 10% to have extras on hand in the classroom in case students lost their materials during the two-week self-study period.

The study incurred no costs to produce and implement the static tool. School computers provided an adequate medium to explore the story map, so the study required no additional hardware to implement the dynamic tool set. The school also provided access to wireless internet in the classroom alleviating concerns over cloud hosting. Alternatively, most students in the classroom owned smart phones that they could have used to manipulate the dynamic tool had the computers been unavailable or access to the internet compromised.

Chapter 5 : Discussion

This study conducted a classroom based, empirical comparison of standard static visualization tools and emerging dynamic Esri story map visualizations. The study focused on answering three research questions intended to demonstrate whether dynamic story maps deserved additional consideration as a viable teaching aid in the classroom, and to add to the existing body of visualization literature: Are their measurable increases in student performance in knowledge extraction tasks; Do story maps increase the likelihood of transitioning ideas from short-term to long-term memory; and do story maps facilitate critical thought through active participation with the data as it is presented? Although the study hypothesized that the dynamic tool would outperform the static tool in all three research objectives, the study design implemented a two-tailed T-test based on the null hypothesis that neither tool offered students a distinct advantage.

The following chapter provides a discussion of the findings from the classroom based experiment in section 5.1, broken down further by research question in sections 5.1.1 through 5.1.3, and a general discussion of qualitative findings in section 5.1.4. Section 5.2 discusses the overall strengths and weaknesses of the research design. Implications for future research are highlighted in section 5.3. The chapter concludes with a summary of conclusions from the research in section 5.4.

5.1 Discussion of Findings

5.1.1. Student Performance on Knowledge Extraction Tasks

The study found that when looking at the full population of students within each research group, student performance in how effectively they answered the questions on the exam tool supported the null hypothesis. Although the control group (Static) earned higher mean scores in three of the four question formats, relatively high P-scores in all but the Fill-in-the-blank format suggest that the differences between the groups are more likely a result of chance. The same tendency repeated itself when the study focused solely on the male population. Although male students in the experimental group (Dynamic) outperformed their peers in the control group in all four formats, the differences between the scores were largely insignificant. They could have easily been reported in reverse in another random sampling as confirmed by high P-scores across the board. However, isolation of the female student population revealed statistically significant findings in favor of the alternate hypothesis.

Although the difference in scores on the fill-in-the-blank format only reflected a 0.97 point difference between the control group (Static) and the experimental group (Dynamic), the statistical significance of the finding was confirmed with a P-score of 0.03 at 95 percent confidence. In fact, female performance in knowledge extraction favored the static tool so heavily, that their scores on the Fill-in-the-blank questions pulled the general population P-score to 0.14. The male population observed a P-score of 0.80 on the same questions.

Student efficiency scores in knowledge extraction further support these findings. On average, students in the control group (Static) answered an additional two questions (1.75) more than their peers in the experimental group (Dynamic) during the first study iteration. The T-test confirmed the statistical significance of the finding at 90 percent with a P score equal to 0.06. However, looking at the efficiency score for the full population does not provide a completely accurate account. Approaching efficiency by gender explains why the general population scores deserve scrutiny.

Male students in the experimental group (Dynamic) earned a slightly higher mean efficiency score than the control group (Static), 14.91 to 14.85. It was the female students in the control group answering an additional three questions more than the experimental group that caused the general population mean to appear significant. The T-test confirmed the statistical difference in efficiency scores between females in the control group and females in the experimental group, producing a P-score of 0.01 at 95 percent confidence.

Based on the study's findings, both tools produced similar results in the general population. Analysis by age failed to return any statistically significant findings, but isolation of the gender variable revealed that female students tended to perform knowledge extraction task more effectively and efficiently when using static products. Interestingly, the study's findings showed the opposite for male students. Based on scores from this study, males performed knowledge extraction more effectively and efficiently using the dynamic story map. Unfortunately, their scores did not reveal statistically significant findings indicating the need for further research to ascertain whether the trend holds or was merely a result of chance.

5.1.2. Impact on Transition to Long Term Memory

The study demonstrated that neither tool led to statistically significant increases in transitioning ideas from short-term to long-term memory. However, students in the experimental group (Dynamic) did demonstrate slightly lower scores in three of the four formats (including spatial analysis), indicating slightly higher retention of concepts between the two study iterations. Also worth noting, female students in the experimental group demonstrated greater transition to long-term memory in all four formats. Whereas female students struggled to extract information using the dynamic tool during the first iteration of the study, initial findings indicate that their increased interaction with the data did lead to greater retention of the information that they learned.

The study's findings related to student efficiency scores on knowledge retention tasks can be interpreted in two ways. The first trend which immediately pops out when viewing student completion times reflects the amount of effort each group put into answering questions on the research tool during the second iteration of the study. With the exception of students in the age 16, and age 17 to 18 populations, the experimental group (Dynamic) spent more time responding to questions. In fact, students in the experimental group, age 14 to 15 population, used an additional 5.38 minutes on the exam than their peers in the age 14 to 15 control group population. T-test further confirmed the very statistically significant value of the recorded discrepancy, producing a P-score of 0.0026 at 95 percent confidence.

The immediate impulse when viewing such a large discrepancy is to conclude that the experimental group (Dynamic) took the second exam more seriously. However, when measured against their effectiveness scores, this conclusion fails. Not only did students in the age 14 to 15 control group (Static) retain essentially the same amount of information between the two study iterations as their peers in the experimental group, but they recalled the information using far less time indicating a far stronger connection with the study material. The same argument holds for the general population of each group. T-test demonstrated a statistically significant difference between the two groups at 90 percent confidence ($P = 0.07$). However, older students demonstrated the opposite tendency. Their mean effectiveness and efficiency scores reflect a stronger tendency toward confirming the study's hypothesis. However, the extremely small population size of the 17 to 18-year-old students in the experimental group failed to influence the findings in the general population.

5.1.3. Implications for Increasing Critical Thought in Students

The lack of responses attempted on the exam tool's essay questions during the first iteration speaks more to the efficiency with which each group employed their designated study tool for knowledge extraction tasks than anything else. Many of the additional questions that the control group (Static) received credit for attempting in the first iteration came from the essay portion of the exam, reflected in their 19 percent higher response rate over the experimental group (Dynamic). By the second iteration, both groups increased their percentages and responded to the essay questions at about the same rate. The initial disparity in attempts drove down mean scores in each group, but it particularly affected the outputs from the experimental group on the mean critical thought scores. This explains why during the first iteration, the study recorded a statistically significant difference between the control group's responses to the first essay question, and the experimental group's, but failed to repeat the same finding during the second iteration of the study. It also accounts for the extremely statistically significant findings the study captured related to the increase in scores between iterations for both groups.

Despite the disparity of attempts between the two iterations identified in both groups, the critical thought findings remained consistent when adjusted for the count. For example, when reviewing responses by count, the control group nearly doubled their attempts, from 50 in the first iteration to 91 in the second iteration. However, their higher level thought scores remained fairly consistent at 50 percent and 51 percent respectively. Similarly, the experimental group more than tripled their initial attempts at the essay responses in the second iteration going from 30 to 96, but despite the dramatic increase in response levels, their scores too remained consistent at 40 percent and 45 percent higher level responses respectively. In both instances, students in the control group recorded a higher percentage of increased levels of critical thought.

The consistency in scores recorded for each group, when only graded attempts were taken into account, seems to confirm that the increase in performance demonstrated by the control group (Static) and the experimental group (Dynamic) reflects an increase in attempts. It does not indicate an increased average score as the raw numbers indicate. Therefore, it would be inaccurate to conclude that students from either group improved their performance significantly between iterations based on higher mean scores achieved by each group.

Again, as with the previous research questions, the study identified gender as a critical factor influencing the way that students interacted with the study tools to demonstrate higher orders of thought. Male students actually demonstrated equivalent levels of critical thought using both tools. By mean scores, the males failed to produce any statistically significant differences in scores between the tools that would indicate a preference in learning styles. The study confirmed these findings by looking at the males' scores by count. During the first iteration, the control group only outperformed the experimental group by 3 percent. During the second iteration, the experimental group reversed the results and outperformed the control group by 1 percent. However, the female population reflects a much different result.

Female students exhibit a strong inclination toward static visualization tools. Beyond the fact that female students in the control group (Static) outperformed the experimental group (Dynamic) by statistically significant margins on both of the essay questions the experimental group attempted during the first iteration, they also reflected significantly greater scores by count. Using the static tools, female students in the control group consistently demonstrated higher level thought in approximately 50 percent of their responses. The experimental group barely approached 40 percent on the second iteration and failed to record a single higher level response while working directly with the story map.

The large disparity reaffirms the study's earlier findings that the female students in the experimental group experienced difficulty with knowledge extraction tasks. Had it simply been a matter of lower critical thought performance, the study should have recorded a higher level thought percentage closer to 40 percent in the first iteration like they achieved during the second iteration without the dynamic tool. At a minimum, the study should have recorded at least one attempt out of those submitted that earned credit for a higher level response. The fact that the female student population from the experimental group was the only population in the study to fail to record a single higher level response during the first iteration of the study speaks volumes. Rather than reflecting a lack of critical thought, which their performance during the second iteration clearly demonstrated they possessed, their scores from the first iteration are more indicative of a hurried response at the last minute as time ran out in the class period.

Age also appeared to play a factor in how the research groups responded to the different tools. Students in the experimental group's 14 to 15 age population reflected similar challenges as the females in working with the dynamic tool set. Their minimal attempts on the essay questions during the first iteration are clearly indicative of challenges with using the study's story map tool. Students age 14 to 15 in the experimental group responded at 29 percent of the rate (8/28) as their peers in the control group during the first iteration. However, during the second iteration, the same population outperformed their peers in the control group in both number of responses (61 to 40) and quality of responses demonstrating higher level thought (48 percent to 33 percent). In fact, the students in the age 14 to 15 population of the experimental group are the only population in the study's experimental group to demonstrate significantly greater levels of critical thought than their peers in the control group during the second iteration of the study.

Although the study recorded full participation from students in the experimental group (Dynamic), only seven of the students in the group actually accessed the material on their own during their two week self-study period. The control group (Static) reported ten students who took advantage of the opportunity. The lack of self-motivated study in both groups indicated that neither tool inspired significant excitement in the students, but perhaps more telling were the student responses as to why they ignored the tool in between iterations, a lack of interest and time. It is fair to assume that neither group reflected on the study material between iterations, making the increase in performance level witnessed in the female and age 14 to 15 populations in the experimental group that much more significant. To answer the essay questions during the second iteration, they needed to recall the information they learned while using the story map. This would further indicate that they knew the answer to the questions, but ran out of time to formulate coherent thoughts during the first iteration.

5.1.4. General Observations

In chapter 2, the study identified that visualization methods should be selected for their ability to communicate to the user in the most effective and efficient manner. While it would appear, based on the findings articulated in chapter 4, that the students in the control group performed knowledge extraction tasks more efficiently than those in the experimental group, what if the study looked at efficiency through a different lens? What if the study employed financial burden on the school or classroom teacher as the measurement for efficiency?

When developing the research design, the study took financial costs associated with developing static tools for granted. However, the costs incurred to develop the static tools deserve serious consideration, and may be a previously unidentified justification for integrating dynamic GIS tools into the classroom for social sciences. The study spent $500.00 on lesson materials for less than half of the total student population belonging to the classroom teacher. To develop materials for the entire student population, the costs would likely double. For one lesson, not included in the standard curriculum textbook, the materials could wind up costing the school or teacher well over $1,000.00 in materials to produce. In contrast, the story map costs absolutely nothing to produce.

Another advantage to using story maps in the classroom is that the lessons can be repeated indefinitely. Unlike custom static tools which must either be retrieved following the lesson, or re-produced (incurring additional financial burden) for future classes, dynamic tools enable students to carry the lesson with them without causing undo financial hardship. If they lose the link to the data, the educator simply re-provides it, and the problem resolves itself. Story maps provide educators with a cost effective means of professionally developing new content to enhance their existing curriculum that would have previously been unavailable.

The study's findings also support a similar discussion regarding the effectiveness of story maps in expanding new lesson materials. Although the findings don't support the original hypothesis that story maps result in greater performance in knowledge extraction, improved transition of ideas to long-term memory, or enhanced critical thought, overwhelming support for the null hypothesis does indicate that they do not detract from any of those objectives either in most instances. In some regard, the study stands as proof of the concept that story maps can introduce new ideas in the classroom just as effectively as traditional methods. However, the cost of producing static tools makes expanding lesson content impractical, particularly when using color ink. Therefore, the study concludes that in terms of developing new lesson content to enhance current curriculums, the story map outperforms static tools in terms of efficiency (cost) and effectiveness (practicality of implementation).

5.2 Assessment of Study Design Strengths and Weaknesses

5.2.1. Strengths

Tversky, Morrison, and Betrancourt identified the primary weakness existing in most visualization research where dynamic tools outperform static variants as a lack of parody in the research tools. (2002) This study made it a point to isolate the methods of delivering information to the students in the research groups by ensuring that both tools reflected the same information. If anything, this study swung the pendulum too far toward parody, opting to remove several features from the dynamic tool that would have increased student performance in the experimental group (Dynamic). Specifically, the study chose a story map format that prevented students from interactively layering data through the use of the swipe tool, or spyglass techniques. It also refrained from introducing interactive layers to depict a line of sight analysis and proximity, as neither would be available to the students using static tools in the control group. Instead, the study included the static maps depicting both sets of analysis in the dynamic tool as pop-ups that the students in the experimental group could control as required to answer associated questions in the exam tool. Ultimately, the dynamic tool reflected the same information as the static tool, with no additional details or opportunities for interactive engagement that would skew the findings.

Along the same lines, selecting the Bascom Affair for the study proved to be a positive decision. Students understood enough about United States history to place the event in the context of western expansion. However, no one had previously learned about the event itself. The students entered the study without pre-existing knowledge, ensuring that the research tool provided their only source of knowledge for the study.

Finally, Isolation of gender and age variables in each research group also proved to be strengths in the research design. The effectiveness of visualization methods varies by age, gender, culture, and other characteristics that shape the way people view and interpret information. (Slocum et al. 2001) Incorporating two such factors provided the study the opportunity to explore variance in responses. Isolation of gender in particular produced statistically significant findings that the study would have missed completely in the general population.

5.2.2. Weaknesses

In chapter 2, the study argued that animated products could be interpreted as static maps due to the inability of the user to alter the data beyond how the creator originally intended. The story map used in this study is vulnerable to the same criticism. Although students in the experimental group retained the ability to manipulate the web map, the study turned many of the interactive features off. The consequence of focusing on parody between the tools is a neutered dynamic tool that fails to accurately portray the tool's inherent strengths. The study concedes the importance of parody, hence the decision to enforce it in the research design. However, outside of a research environment, none of the same constraints apply. At some point, research needs to demonstrate the full capacity of dynamic tools. Story maps clearly provide educators an advantage at introducing increased levels of student interactivity within new lesson content. However, in the name of parody, the study purposely decreased the opportunities available to the experimental group.

In addition to the techniques discussed under strengths that the study decided to forgo, one of the major advantages inherent to dynamic visualization methods is the ability to hyperlink additional resources directly into the lesson content. Shortening the distance between the student and sources of external information by embedding links directly into the lesson content increases the likelihood that they will pursue additional research on the topic. In fact, even without hyperlinking external sources, the study still observed a student attempting to pursue additional research. As previously discussed, the action invalidated the student's results, but it also supports the argument that dynamic products increase interaction with the data as it is presented.

Sample size also posed a challenge to the initial research design. Although sufficient sample sizes participated in the general population for each research group, when the study isolated age and gender variables the sample sizes decreased significantly. Small sample sizes posed a particular challenge to students in the 16-year-old and 17 to 18-year-old age populations. Although the study produced statistically significant findings in each group, the sample size calls the validity of those findings into question in those populations.

Finally, time posed the most significant challenge to the study. With few exceptions, students from both research groups failed to respond to all of the questions on the research tool in both iterations. The study was restricted to a 55 minute class period, but ideally, students would have as long as they required to respond to each question for the study to develop a true estimate of the mean time required using each tool. Also, because the study leveraged a single teaching opportunity, students from the control group enjoyed a distinct advantage. They used a familiar format to answer the questions on the exam tool. The students in the experimental group had never used a story map prior to the study, so they had to contend with learning to manipulate the new technology.

Time on the day of the study was not the only challenge. A large percentage of students from both groups reflected that their official studies and extra-curricular programs prevented them from capitalizing on the two week self-study period, which was designed to increase their exposure to their assigned research tool. Ultimately, the study's findings are heavily influence by the lack of time each group had to familiarize themselves with the tool. This particularly hurt the experimental group (Dynamic) because they had to learn to use an unfamiliar format.

5.3 Implications for Future Research

Despite the weaknesses in this study, the research identified several statistically significant findings related to how female students interact with visualization tools. Future research should continue to incorporate gender as a variable for consideration in its design. In particular, although male students failed to produce statistically significant differences with either tool, their mean scores heavily favored the dynamic tool. Taken in context with the female population's demonstrated preference for learning with static tools, this may represent a significant finding with implications for how each gender interprets spatial visualization methods. Further research should focus on further developing how each gender interacts with the different tool sets.

Access to a single campus restricted the availability of respondents. After removing students from the study that could not participate due to a lack of parental permission or were disqualified from the findings due to unsanctioned behavior (group work in the control group and looking up external references in the experimental group), the study maintained a respectable population size of 101 students. Future research should apply the framework developed in this study to reach greater populations across a wider demographic spread. In particular, future research should attempt to enter both public and private campuses across different geographic regions, all-male and all-female schools, and Schools with a heavy emphasis on Science, Technology, Engineering, and Math (STEM) to see how the different environments influence the study's findings.

Future research should also attempt to increase the length of the study. This study focused on a single class period and lesson plan. However, developing the study to take place over the length of a semester, or school year, as part of the students' regular class load will significantly increase the significance of findings by enabling the researcher to incorporate multiple lesson plans across a variety of topics. A larger body of work, over an extended period of time, should reduce the impact that students in the experimental group felt from learning to use the new technology. Finally, incorporating the research into the student's coursework will reduce the level of distraction and force them to focus on the study as part of their regular instruction.

A longer research design should also strive to incorporate the interactive features that story maps support, and use multiple formats of the application to provide a more holistic view of the technology's capabilities in the classroom. Over the course of a semester, or school year, maintaining parody between static and dynamic tools will likely be impractical. However, full implementation of both tools in the classroom environment in an unconstrained manner will provide a clearer picture of the true strengths and weaknesses of each tool.

5.4 Conclusions

In 2013, Lunen and Travis argued that future research needed to focus on determining *WHY* historians should embrace GIS by demonstrating concrete examples of gains that the field would incur through incorporating the technology. (Lunen and Travis 2013) In the same year, Kerski, Demirci, and Milson recommended establishing a base of research for the same purpose from a secondary school perspective, to empirically demonstrate *WHY* GIS makes a difference in education. Rather than continuing to focus on *HOW* to implement the technology in the classroom, the researchers recommended pursuing data that shows educators how GIS technology is an improvement over their current teaching strategies.

Lisner’s findings in 2008 validated the shift in focus from demonstrating new teaching methods, to identifying evidence of improvement in student performance that results from adopting the new technology. As her research identified, the teachers who had already made the transition did so overwhelmingly because they felt that GIS offered their students an increased advantage over traditional classroom tools. (Lisner 2008) To justify the personal risk that classroom teachers assume when transitioning to new technologies, research needs to demonstrate that GIS implementation results in quantitative increases in student performance.

This study intended to demonstrate why GIS integration into secondary school social science curriculums benefits students in the classroom. Although it failed to disprove the null hypothesis, the study produced several findings of note to high school social science teachers. First, it confirmed the findings from previous visualization research indicating that students perform at the same level or better when using static visualization aids as opposed to dynamic products. Despite the fact that the study employed a simplified dynamic tool in the form of a story map, the new format still posed a challenge to students performing knowledge extraction tasks. The study produced findings of particular interest to teachers working with freshmen and sophomore populations, and those on single-gender campuses Females and younger students (age 14 to 15) in the study exhibited the most difficulty with the dynamic tool set, producing statistically significant findings that favored the use of static products in the classroom.

However, the study also identified insights that indicate student performance with the dynamic tools may improve as familiarity increases. Poor performances from the experimental group on the critical thought questions reflected a lack of time for thought, rather than a lack of knowledge learned. Without studying between iterations, the female and younger student (14 to 15) populations significantly improved their performance on the second iteration. Female students in the experimental group also demonstrated greater success at retaining information between the iterations.

Finally, the study produced unexpected qualitative findings that support the viability of using story maps to improve the depth of curriculums in secondary school social science classrooms. Financially, schools and classroom teachers can’t afford to create new content regularly with standard static products. Production costs are often prohibitive, reducing the likelihood of implementing new content. Story maps provide an effective teaching aid that matches the quality of current classroom tools at a price that teachers can realistically hope to employ in their classrooms.

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Appendix A: Institutional Review Board (IRB) Documentation

USC Jason Martos <martos@usc.edu>

Study Approval Notice Sent

istar@istar.usc.edu <istar@istar.usc.edu> Fri, Nov 20, 2015 at 7:46 AM
Reply-To: istar@istar.usc.edu
To: martos@usc.edu, warshaws@usc.edu

USC Children's Hospital LOS ANGELES LAC+USC iStar

University of Southern California University Park Institutional Review Board
3720 South Flower Street Credit Union Building (CUB) #301
Los Angeles, CA 90089-0702
Phone: 213-821-5272
Fax: 213-821-5276
upirb@usc.edu

Date:	Nov 20, 2015, 09:44am
Action Taken:	**Approve**
Principal Investigator:	Jason Martos, M.S. SPATIAL SCIENCE
Faculty Advisor:	Daniel Warshawsky SPATIAL SCIENCE
Co-Investigator(s):	
Project Title:	**Visualizing Historic Space: A Comparison of Static versus Dynamic Methods**
Study ID:	**UP-15-00668**
Funding Types:	No Funding

Researchers are reminded that only those persons listed in sections 2.1 (if affiliated with USC) and/or 2a (if not affiliated with USC), appropriately trained and qualified with current CITI/Human Subjects Certification should conduct study related activities, including the consent process, collecting data and/or analyzing data.

Attachments: No documents

The University Park Institutional Review Board (UPIRB) designee determined that your project meets the requirements outlined in 45 CFR 46.101(b) **category (1)** and qualifies for exemption from IRB review. This study was approved on **11/20/2015** and is not subject to further IRB review.

Minor revisions were made to the application (sections 9.2, 11.1, 11.2 & 24.1.2) and the combo Parental Permission & Youth Assent Form by the IRB Administrator (IRBA). The IRBA revised documents have been uploaded into the relevant iStar sections. If revisions are made to the application, and changes are required to the documents, please create an amendment, at which time the IRBA revised documents will become available to the study personnel. All current changes must be accepted using the track changes feature in Microsoft Word and the changes saved. The study personnel can then revise the documents, including the date in the footer. The PI/study staff revised documents must then be uploaded into iStar using the "upload revisions" function; thereby replacing the obsolete documents. Please do **not** remove the obsolete version from the application.

The following materials were reviewed and approved:
Certified Parental Permission & Youth Assent Form, dated 11-20-2015

To access IRB-approved documents, click on the "Approved Documents" link in the study workspace. These are also available under the "Documents" tab. The consent document can be utilized as a recruitment tool.

Please check with all participating sites to make sure you have their permission to conduct research prior to beginning your study.

Researchers are reminded that only those persons listed in sections 2.1 (if affiliated with USC) and/or 2a (if not affiliated with USC), appropriately trained and qualified with current CITI/Human Subjects Certification should conduct study related activities, including the consent process, collecting data and/or analyzing data.

Social-behavioral health-related interventions or health-outcome studies must register with **clinicaltrials.gov** or other International Community of Medical Journal Editors (ICMJE) approved registries in order to be published in an ICJME journal. The ICMJE will not accept studies for publication unless the studies are registered prior to enrollment, despite the fact that these studies are not applicable "clinical trials" as defined by the Food and Drug Administration (FDA). For support with registration, go to www.clinicaltrials.gov or contact Jean Chan (jeanbcha@usc.edu, 323-442-2825).

Approved Documents: view

This is an auto-generated email. Please do not respond directly to this message using the "reply" address. A response sent in this manner cannot be answered. If you have further questions, please contact iStar Support at (323) 276-2238 or istar@usc.edu.

Appendix B: IRB Certified Youth Assent-Parental Permission Form

University of Southern California
Spatial Science
3616 Trousdale Parkway, AHF B55B
Los Angeles, CA 90089-0374

YOUTH ASSENT-PARENTAL PERMISSION FOR NON-MEDICAL RESEARCH
This form will also serve as the "Youth Assent" and "Consent/Permission form for the Youth to Participate in Research." In this case, "You" refers to "your child."

Visualizing Historic Space: A Comparison of Static versus Dynamic Methods

You are invited to participate in a research study conducted by Jason Martos, under the supervision of Daniel Washawsky, Ph.D., from the University of Southern California. Your participation is voluntary. You should read the information below, and ask questions about anything you do not understand before deciding whether to participate.

Please take as much time as you need to read the consent form. Your child will also be asked his/her permission. Your child can decline to participate, even if you agree to allow participation. You and/or your child may also decide to discuss it with your family or friends. If you and/or your child decide to participate, you will both be asked to sign this form. You will be given a copy of this form.

PURPOSE OF THE STUDY
The purpose of this study is to find out how students interpret data through maps in the classroom

STUDY PROCEDURES
To develop its findings, the study uses standard classroom instruction methods and testing materials to identify which form of mapping most effectively communicates the lesson material to students in high school classrooms. As part of the visualization study, your son or daughter will:

a. Receive 20 minutes of instruction on an event in United States' history, designed to meet Hawaii state standards, using standard paper maps (control group) or digital Esri Story Maps (experimental group) to supplement the lesson plan.

b. Participate in two tests based on the lesson material, and aligned with Hawaii Content and Performance Standards III in Social Studies. The tests will be administered approximately two weeks apart, and are provided for the purpose of determining: If story maps improve student learning; if story maps improve memory retention; and if story maps improve critical thought through active participation with the lesson material.

Students will be assigned into one of two groups the control group or experimental group by class.

POTENTIAL RISKS AND DISCOMFORTS
There are no anticipated risks or discomforts to your participation. The teacher will be present in the room at all times during the lesson and exam periods.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY
It is hoped that this study will help improve instructional methods used by teachers in the classroom by helping to understand how high school students interpret data from maps. This study represents an initial step toward developing a base of research that demonstrates why teachers should include Geographic Information Science and Technology in their curriculum development, and may add to existing literature by expanding upon current research into static versus dynamic visualization methods.

CONFIDENTIALITY
No personally identifiable information will be retained by the researcher in the conduct of this study. You will receive a non-attributable participant identification number that will be used by to verify any changes in scores between the two tests administered. We will keep your records confidential as far as permitted. However, if we are required to do so by law, we will disclose the data collected during the study. The members of the research team and the University of Southern California's Human Subjects Protection Program (HSPP) may access the data. The HSPP reviews and monitors research studies to protect the rights and welfare of research subjects.

As a USC employee, the researcher is required to report any known or suspected abuse or neglect relating to children to USC's Department of Public Safety (DPS) and the Department of Children and Family Services (DCFS)

Upon completion of the data collection and data entry, all hard copies (this parental permission-youth assent document, test papers, etc.) will be destroyed. The digital data will be stored on a password protected computer in the researcher's office for three years.

PARTICIPATION AND WITHDRAWAL
Your participation is voluntary. Your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study.

ALTERNATIVES TO PARTICIPATION
If you choose not to participate in this study, you will be provided with an alternative GIS based project to complete. Your grades will not be affected, whether or not you participate in this study.

INVESTIGATOR'S CONTACT INFORMATION

If you have any questions or concerns about the research, please contact the Principle Investigator, Jason E. Martos via phone: 909-731-2228 or email: martos@usc.edu or the Faculty Advisor, Daniel N. Warshawsky, Ph.D. via phone: (213) 740-2876, Fax: (213) 740-9687 or email: warshaws@usc.edu.

RIGHTS OF RESEARCH PARTICIPANT – IRB CONTACT INFORMATION

If you have questions, concerns, complaints about your rights as a research participant or the research in general and are unable to contact the research team, or if you want to talk to someone independent of the research team, please contact the University Park Institutional Review Board (UPIRB), 3720 South Flower Street #301, Los Angeles, CA 90089-0702, (213) 821-5272 or upirb@usc.edu

SIGNATURE OF RESEARCH PARTICIPANT (If the participant is 14 years or older)

I have read the information provided above. I have been given a chance to ask questions. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Participant

____ ____________________
Signature of Participant Date

SIGNATURE OF PARENT(S)/LEGALLY AUTHORIZED REPRESENTATIVE

I have read the information provided above. I have been given a chance to ask questions. My questions have been answered to my satisfaction, and I agree to allow my child participate in this study. I have been given a copy of this form.

____
Name of Parent/Legally Authorized Representative

____ _________________
Signature of Parent/Legally Authorized Representative Date

SIGNATURE OF INVESTIGATOR

I have explained the research to the participant and his/her parent(s)/Legally Authorized Representative, and answered all of their questions. I believe that the parent(s) understand the information described in this document and freely consents to participate.

____

Name of Person Obtaining Consent

______________________________________ ____________________

Signature of Person Obtaining Consent Date

Appendix C: Hawaii Department of Education Data Sharing Agreement (DSA) and Work Plan

DSA2015062

Data Sharing Agreement
between
Jason Martos
and
Hawaii Department of Education

This data sharing agreement allows the Hawaii Department of Education (HIDOE) to share individual student or staff data and/or personally identifiable student information (hereafter "PII") from education records to Jason Martos for the following purpose(s):

- To conduct research on cartographic visualization methods in partial fulfillment of degree requirements for Jason Martos toward the completion of a Master of Science in Geographic Information Science and Technology through the University of Southern California (USC).

This agreement authorizes Jason Martos access to the data in accordance with the Family Educational Rights and Privacy Act (FERPA), 34 CFR §99.31, in order to conduct a research project on behalf of HIDOE. Disclosing data/information from education records to Jason Martos in no way assigns Jason Martos ownership of the data/information or records; therefore, the data/information and/or records may be re-disclosed only with written permission from HIDOE or otherwise in compliance with FERPA and its regulations.

Attached to this data sharing agreement is a detailed work plan describing the data sharing activities related to the project "Visualizing Historic Space through the Integration of Geographic Information Science in Secondary School Curriculums: A Comparison of Static versus Dynamic Methods." Other related documents will be kept on file by HIDOE for reference, review and in the course of an audit, including certificates of completion from the project lead(s)/principal investigator(s) listed in the attached work plan for the online training "FERPA 101: For Local Education Agencies," available at http://ptac.ed.gov.

1. Start Date: Upon full execution of this agreement.

2. End Date: May 31, 2016

3. Names and positions of non-HIDOE personnel authorized to access the data:
    - Jason Martos, Researcher – USC Spatial Sciences Institute
    - John Wilson, Director/Advisor – USC Spatial Sciences Institute
    - Darren Ruddell, Advisor – USC Spatial Sciences Institute
    - Kirk Oda, Thesis Committee Member – USC Spatial Sciences Institute
    - Jennifer Swift, Thesis Committee Member – USC Spatial Sciences Institute

- Angela Hasan, Thesis Committee Member – USC Rossier School of Education

Should staff change over the course of the project, Jason Martos must inform HIDOE of any changes to the list above by requesting a modification to the attached work plan. Upon entering into the project, a new project team member will be required to adhere to the terms set forth in this data sharing agreement.

4. Specific data authorized for sharing:
   HIDOE will share the following data with Jason Martos under the study or evaluation exception in FERPA, 34 CFR §99.31(a)(6)(i):
   a. Feedback from administration and classroom teachers relevant to study
   b. Student exam results relevant to the study (de-identified)

5. Limitations to the use and release of the data:
   Jason Martos is authorized by way of this agreement to access the specified data and use said data only to meet the purpose(s) of this agreement. If the data, as a whole, that are presented to Jason Martos contain PII, the entire data set is considered PII and should be handled as such, and is protected under FERPA and this agreement. HIDOE maintains the right to conduct audits or other monitoring activities of Jason Martos policies, procedures and systems. In the event that a violation occurs, Jason Martos may be ineligible to receive PII data for a minimum of five years. HIDOE also reserves the right to pursue legal redress related to the violation. HIDOE has final decision-making authority for all disputes related to this agreement. In the event the agreement is terminated, all data and information derived by the data will be destroyed upon notification of the termination and the authorized representative shall send written verification of the destruction to HIDOE.

6. Data destruction protocols employed by Jason Martos :
   Jason Martos agrees to destroy the data within 30 days after the end date of this agreement. This requirement does not apply to signed consent forms, which, in accordance with 45 CFR §46.115(b) "IRB Records," may be retained for three years after completion of the research.

7. Data protection plan:
   Data will be protected by: restricting collection of information about participants to participant_ID; Personally Identifiable Information will not be collected; student names will be linked to participant_ID by the teacher; teachers will delete Student_Name column prior to returning the master participant list to

the researcher via email; data will be restricted to authorized study personnel; copies of the master participant list will be restricted to authorized study personnel; hard copies of data will be maintained in a locked office and shredded upon completion of the study.

8. Description of disciplinary policy for FERPA violation:
   Jason Martos will fully comply with FERPA by protecting the privacy of student records and the confidentiality of all data in their possession. Should an unintentional violation arise, Jason Martos will report it immediately to HIDOE and take the necessary steps to come into compliance as well as deal with violators within Jason Martos's applicable personnel policies and procedures. In the event Jason Martos learns of a security breach involving the data, Jason Martos must report it immediately to HIDOE as outlined in the guidance document, "Guidelines for Notification of Security Breaches of Personal Information" (available at bit.ly/SecBreachGuide) so that breach notification can occur as required by Hawaii Revised Statute 487N. Any breach is the responsibility and liability of Jason Martos, which, by entering into this agreement, agrees to indemnify and defend HIDOE should HIDOE be found liable as a result of the breach.
   Even if HIDOE shares de-identified data with Jason Martos, Jason Martos will provide HIDOE with a copy of the study results or final report of the study prior to publication for review to ensure that no PII is contained with the document. This includes data such as aggregated counts that are small enough to allow a reasonable person in the school community to identify the student(s) with reasonable certainty.

We, the undersigned, agree to adhere to the terms and conditions specified above.

Hawaii Department of Education Mililani High School Fred Murphy Principal	1/6/16 Date
Jason Martos Graduate Researcher, USC	10 DEC 2015 Date

Appendix D: Static Research Tool

THE BASCOM AFFAIR

"Young officers were often entrusted with important duties, the execution of which affected their military standing more or less ever afterwards… The first paragraph in Army regulations explains the manner in which orders shall be obeyed, and in this spirit, Lieutenant Bascom tried to carry out his orders."

-- SGT Daniel Robinson

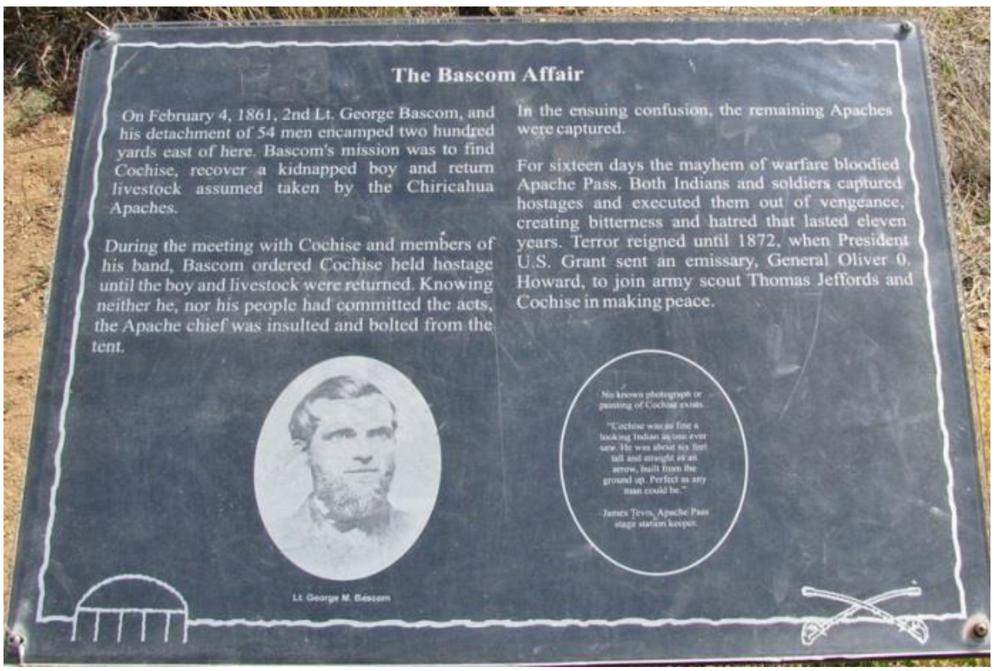


Figure 17 - Plaque located in Apache Pass commemorating the Bascom Affair

IDENTIFYING OUR SPACE…

We use spatial skills to analyze and interpret data from maps relating to people, places, and environments in an attempt to explain the interactions between geographic regions, and various societies throughout history. However, in order to fully appreciate the relationship between humans and geographic space, one must recognize and contend with the, "imaginative quality of their own views." (Mares and Moschek 2013) In other words, you must account for the ways that personal prejudice and preconceived notions influence the manner in which you interpret spatial-temporal data.

A simple question like, "Where are we?" can be answered in several ways depending on the way you approach the question. Take for example the two maps depicting the southwestern United States as it was in 1846 and 1861. Consult the 1861 map's legend to determine when Arizona and New Mexico became United States Territories.

Figure 18 - Map of Texas, California, and Oregon from 1846, originally published by S. Augustus Mitchell in Philadelphia, Pennsylvania (David Rumsey Collection Online 1998)

THE INDEH CIRCA 1861

"Who" is another perspective that is often forgotten. From the United States' perspective, they acquired the lands in present day Arizona and New Mexico through a series of cessions, annexations, and purchases from the Mexican government following the Mexican-American War. However, the Indeh (as the Apache refer to themselves) perceived land ownership somewhat differently... The Indeh inhabited the area on the map long before the Spanish, Mexican, or American governments laid claim.

The Map on this tab depicts the approximate territorial boundaries of the primary Apache bands involved in the Bascom Affair - the event that triggered 25 years of war between the United States and Apache nation. Spend some time reviewing the maps you've been presented with so far to familiarize yourself with the different perspectives of space in question. See if you can identify your own bias before continuing with the lesson.

Figure 19 - Painting of the Apache by David Nordahl

In many respects, when Americans conceive of the Apache Indians they envision the Chiricahua band. This statement rings as true today as in February, 1861 at the onset of the Apache War. In reality, the *Indeh* included several bands of American Indians that spanned the southwest with a combined population of around six thousand people. The Chiricahua settled largely in Southeastern Arizona and portions of New Mexico, and Northern Sonora and Chihuahua.

Although confusion exists as to their true subdivisions, the Chokonen led by Cochise, the Chihenne (Ojo Caliente/Hot Springs) led by Victorio, the Bedonkohe led by Mangas Coloradas, and the Nednhi led by Juh are generally accepted as accurate inclusions. At the very least, strong bonds existed between the four groups and they frequently lived together, raided, and went to war as allies.

Figure 20 - Map by Alonso, depicting the approximate regions of each of the major Apache bands. The Spanish referred to the Apache lands as Apacheria. See if you can spot Apacheria on the map from 1846. (Accessed online at https://apacheria.es/)

THE RAID ON THE WARD RANCH

In January 1861, raiders from the Arivaipa group of the Western Apache band descended upon John Ward's ranch in present day Sonoita, Arizona. They made off with approximately twenty head of cattle, and perhaps most importantly, Ward's twelve year old stepson, Felix. During their escape, the Arivaipa likely laid a false trail to the east to avoid suspicion before heading to their homes along Arivaipa Creek to the North. In any event, Mr. Ward, who had not been present at the attack itself, identified their spoor and immediately blamed Cochise for the incident. He reported as such to Lieutenant Colonel Pitcairn Morrison at nearby Fort Buchanan, who responded by ordering Lieutenant George N. Bascom to pursue the Apaches and use the force under his command to recover the stolen property and Felix Ward.

At the outset, neither party expected the sequence of events that would follow. For Bascom, recovering lost property captured during an Apache raid was a common task. Although Bascom had never participated in direct actions with the Apache himself, by 1861 the Army grew accustomed to policing the Southwest, and likely would have viewed the Ward incident as routine.

CULTURAL CONSIDERATIONS

Apache culture revolved around the practice of raiding, which they depended upon for sustenance to support their nomadic lifestyle. They learned early that established agricultural communities and fixed rancherias meant extinction for their peoples. Not only did the terrain make it difficult to sustain large communities, but fixed sites provided vulnerable targets for Ute and Comanche war parties in the late seventeenth and early eighteenth centuries. The level of violence and destruction visited upon the Apache by the Utes and Comanches in this period dwarfed their losses to Mexican and American forces in the nineteenth century. Of the fourteen Apache groups that ranged as far north as present day Nebraska, and well into central Texas, only the Jicarilla survived the brutal onslaught and retained possession of a small portion of their original land. The remaining Apache bands learned a valuable lesson; survival depended on mobility, concealment, and resourcefulness.

Figure 21 - Example of a common Apache dwelling site established at Fort Bowie, Arizona for visitors to observe.

In the three years after Cochise first met with the United States' Apache agent, Michael Steck, he and his Chokonen had become the most well known group in the region. Anytime violence occurred, he generally received credit for the raid whether or not he played a role. There are several explanations for this, but primarily, Cochise continued to raid after agreeing to let the Butterfield stage line cross through Apache Pass.

The Apache had a difficult time comprehending that the various United States and Mexican settlements shared common governance. Therefore, while Cochise had agreed upon peaceful relations surrounding Apache Pass, he likely did not understand that residents outside of that region fell under the same protections. Similarly, American settlers at the time could not grasp that Apache bands operated autonomously. Cochise and his Chokonen often drew accusations simply because his name carried the most notoriety and most settlers saw him as the Apaches' leader.

The Apache criminal justice system provides yet another explanation for the Chokonen receiving credit for so many depredations during the period when Cochise tried to live at peace with the Americans. When Apaches committed crimes against their own people, the group exiled them. These exiles could not seek refuge with other groups, so they often banded together to form their own support structures. Frequently, the official bands received credit for raids committed by their exiled members. At any rate, although John Ward lacked physical evidence of Cochise's involvement at the time, Lieutenant Colonel Morrison had ample reason to investigate his claim and little reason to suspect that his orders would inadvertently trigger all-out war.

Figure 22 - Geronimo with three of his warriors in Canon de los Embudos; from left to right: Yahnozha, Chappo, Fun, and Geronimo.

THE APPROACH TO APACHE PASS

Several factors indicate that Cochise did not view Bascom as a threat when he arrived at Apache Pass on February 3, 1861 with John Ward in tow as his interpreter and fifty four soldiers of

Charlie Company, Seventh Infantry under his command. Rather than assuming a defensive posture, the Chokonen continued to trade openly with United States soldiers in vicinity of Apache Pass, and approach them without reservation.

Figure 23 - View approaching Apache Pass similar to what LT Bascom and his Soldiers would have enjoyed.

When Cochise went to meet Bascom in his camp, he brought his family in tow. Cochise arrived with his brother Coyuntura, two of his nephews, and most notably his wife Dos-teh-seh (daughter of Mangus Coloradas), and two of their children.

THE CONFLICT BEGINS

Bascom and Cochise met on the morning of February 4, 1861 at Bascom's camp in Apache Pass. Bascom took Cochise and the adult males (Coyuntura, his nephews, and the unnamed warrior) with him into his tent, and instructed his soldiers to form a security perimeter around the site. Through Ward, Bascom accused Cochise of conducting the raid and required that he return Felix Ward. Cochise denied any involvement, but offered to identify the guilty party and bring the boy back if the lieutenant would grant him ten days to account for travel to and from the Black Mountains where he thought the Ward boy to be. Bascom refused, and instead informed Cochise that he would be held prisoner, along with his family, until he returned Felix Ward. At this point, Cochise drew his knife, and cut his way out of the tent, accompanied by the un-named warrior. The warrior fell victim to one of the guards' bayonets, but Cochise managed to escape.

Over the next several weeks, conditions devolved rapidly as Cochise attempted first to intimidate Bascom into releasing his family, then seeing that fail, looked for opportunities to collect hostages as leverage to secure their release. When that failed too, Cochise sought vengeance. Prior to breaking camp and removing the remaining Chiricahua to safety in preparation for war, Cochise ordered the execution of his hostages. Events culminated on February 19, 1861. In retaliation for Cochise's actions, Bascom ordered his soldiers to hang the Chiricahua chief's brother and nephews, along with three additional Apache prisoners captured by his command in the previous weeks. He then took Cochise's wife and children back to Fort Buchanan with him, where the Army eventually released them.

Figure 24 - Remnants of the old Butterfield Stage station at Apache Pass; Cochise collected hostages from the Butterfield station after his initial attempt to intimidate LT Bascom into releasing his family failed.

WHAT WENT WRONG

Why did a routine policing action devolve into to what Cochise later termed, "a very great wrong" committed by Bascom and his soldiers that motivated Cochise and the Chiricahua Apache to unite in war against the United States?

Foremost, Morrison and Bascom made a critical error in their choice of interpreters. John Ward understood nothing of the Apache language or culture, and had poor control of the Spanish language that the mission relied upon to communicate with Cochise. More importantly, Ward approached the situation heavily invested in the outcome, and clearly biased as to who he thought bore responsibility for the raid on his property. Bascom paid for his decision to use Ward immediately, as Ward insulted Cochise the moment he stepped foot in the tent.

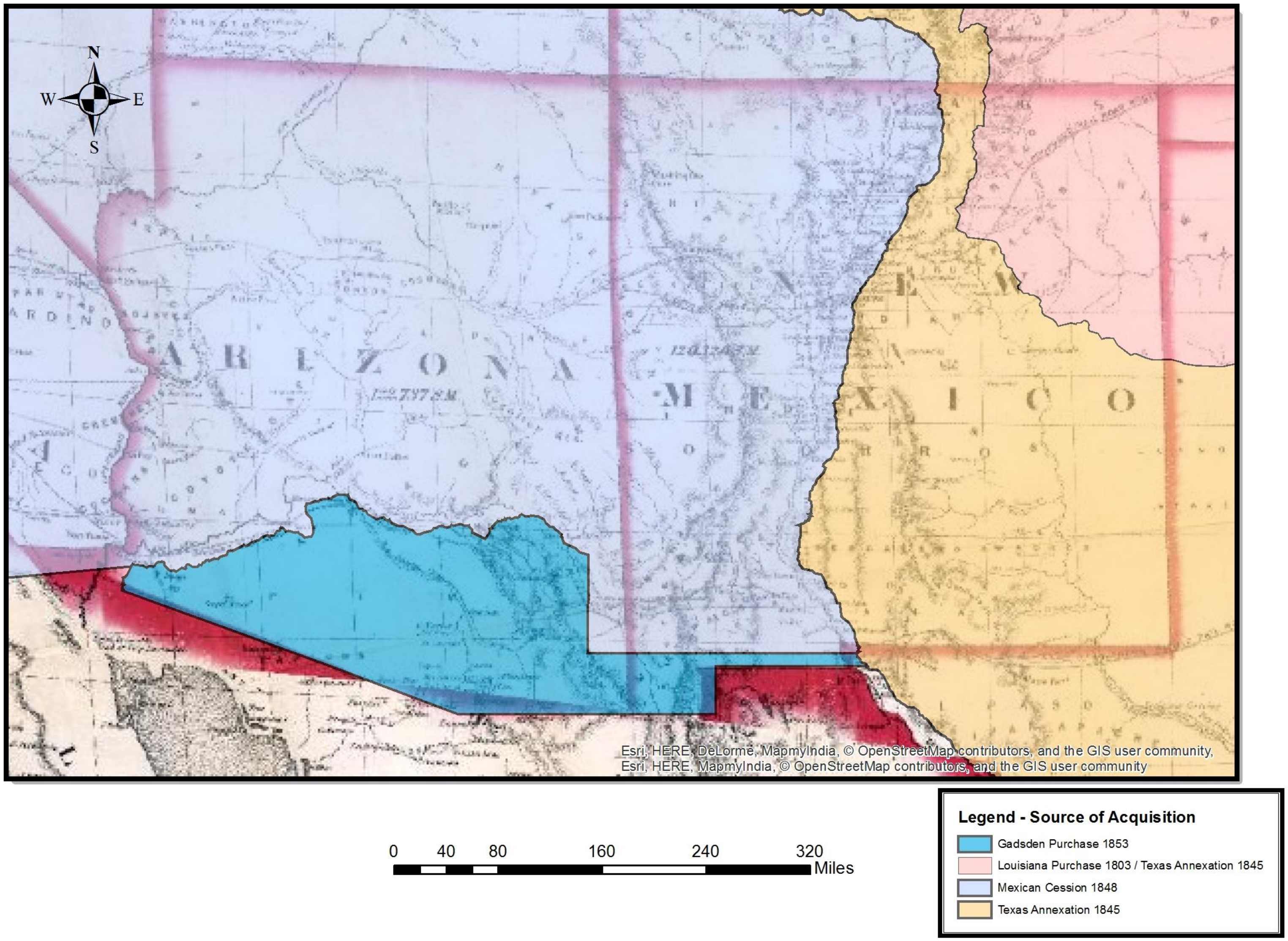
But what of LT Bascom himself? Immediate narratives developed placing the blame for the event at his feet, and modern interpretations of the Bascom Affair continue to follow suit. But was he properly prepared for the task at hand? If as SGT Robinson's quote implied, that young officers were frequently entrusted with significant responsibilities, for which the consequences of failure could potentially lead to war, what did the Army do to prepare their officers for these missions? After all, if the argument can be made that a more seasoned officer would have reacted differently, then it stands to reason that, that officer must have understood something more than Bascom, which means that something in Bascom's development may have been lacking.

Figure 25 - Timeline of major events leading up to the Bascom Affair

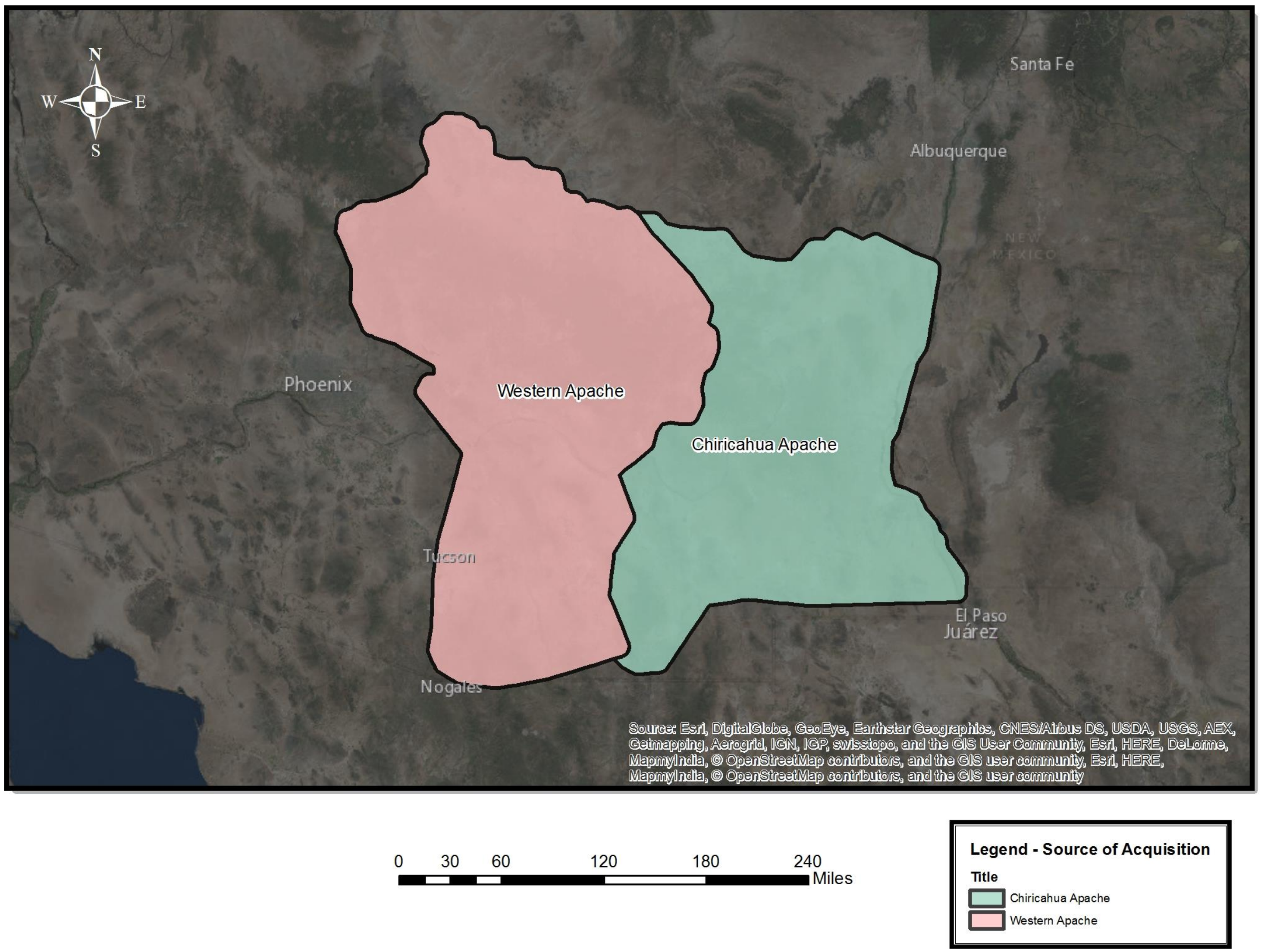
Bascom lacked the skills required to perform the mission that Lieutenant Colonel Morrison ordered him to accomplish: Diplomacy, negotiation, and cultural awareness. West Point certainly did not develop these skills in the officers that they commissioned. Their curriculum focused heavily on math and science, neither of which proved much use to Bascom in Apache Pass.

If Bascom had arrived at Apache Pass fresh off of the trip from the Hudson, it would be fair to lay the blame squarely on his military academy background, but Bascom didn't graduate from West Point in 1860. He graduated the Academy as part of the class of 1858, and had already been an officer for three years when he confronted Cochise. In fact, he had been operating in the Trans-Mississippi West since approximately May of 1859 and served under Morrison's command since the summer of 1860. Ultimately, the Army had three years to professionally develop Bascom, to share with him the knowledge that would have allowed a more seasoned officer to successfully negotiate with Cochise to recover John Ward's property and son. Unfortunately, none of his superior officers felt the endeavor merited consideration.

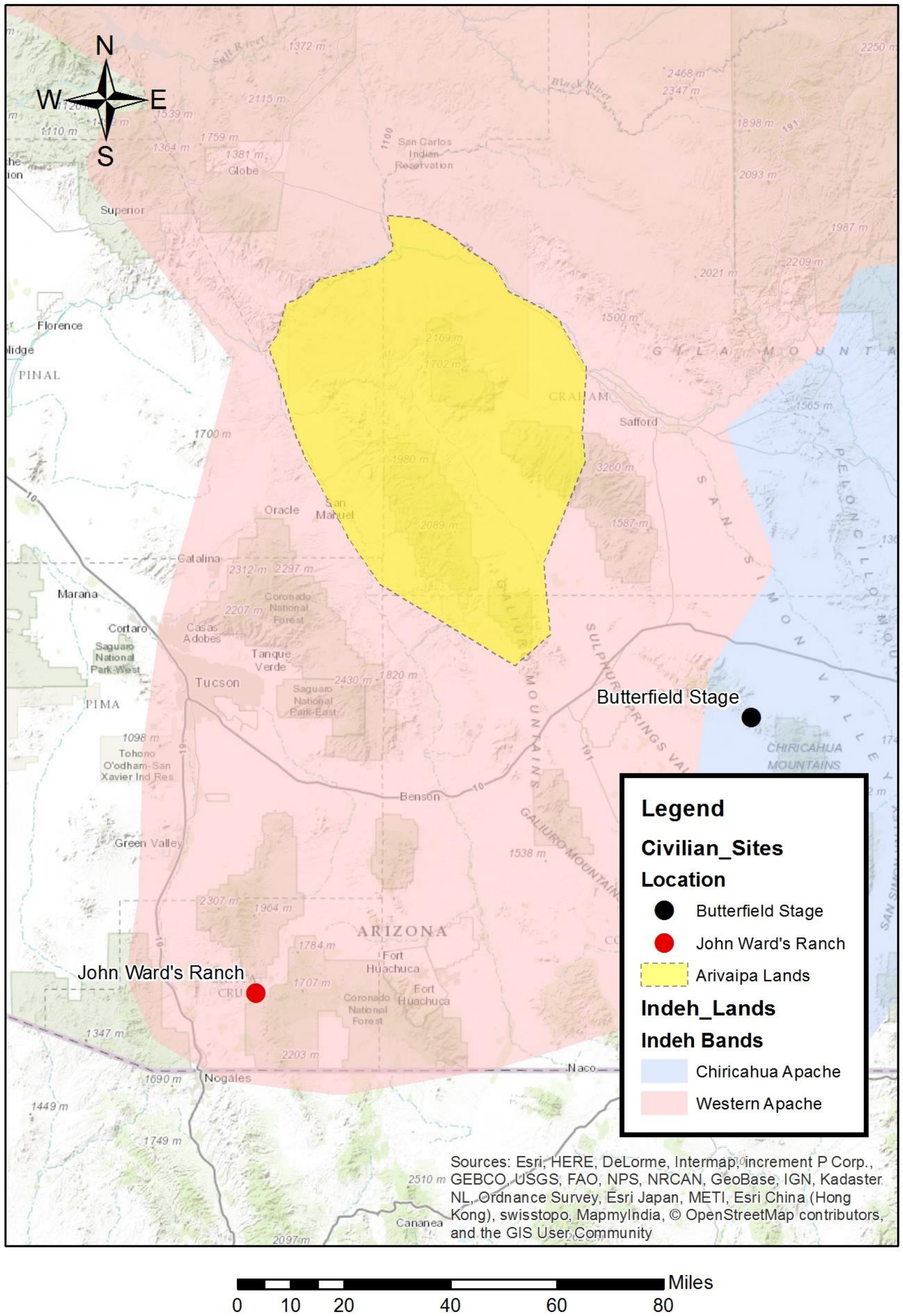
Arizona and New Mexico Territories Circa 1861



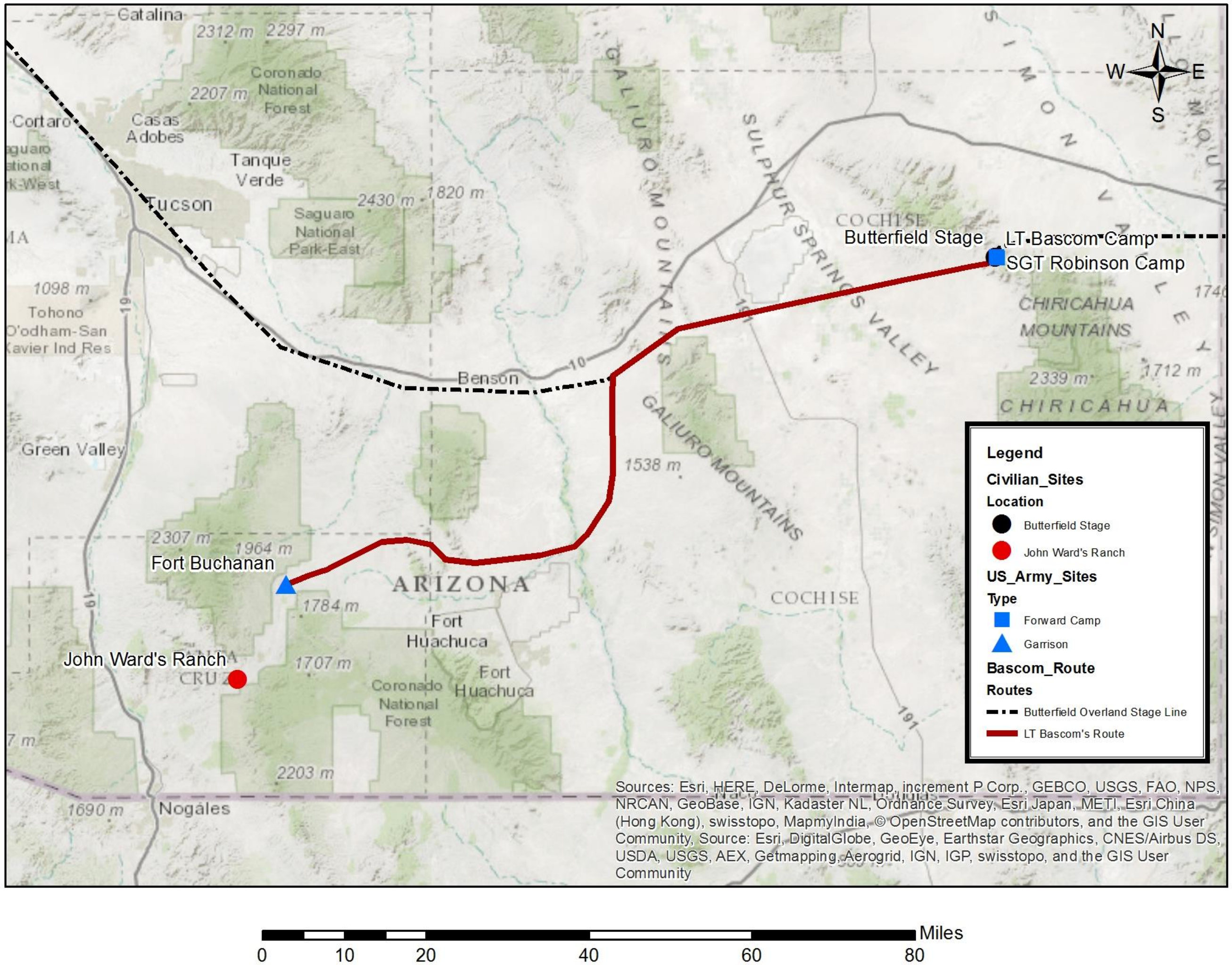
Chiricahua and Western Apache (Indeh) Lands Circa 1861



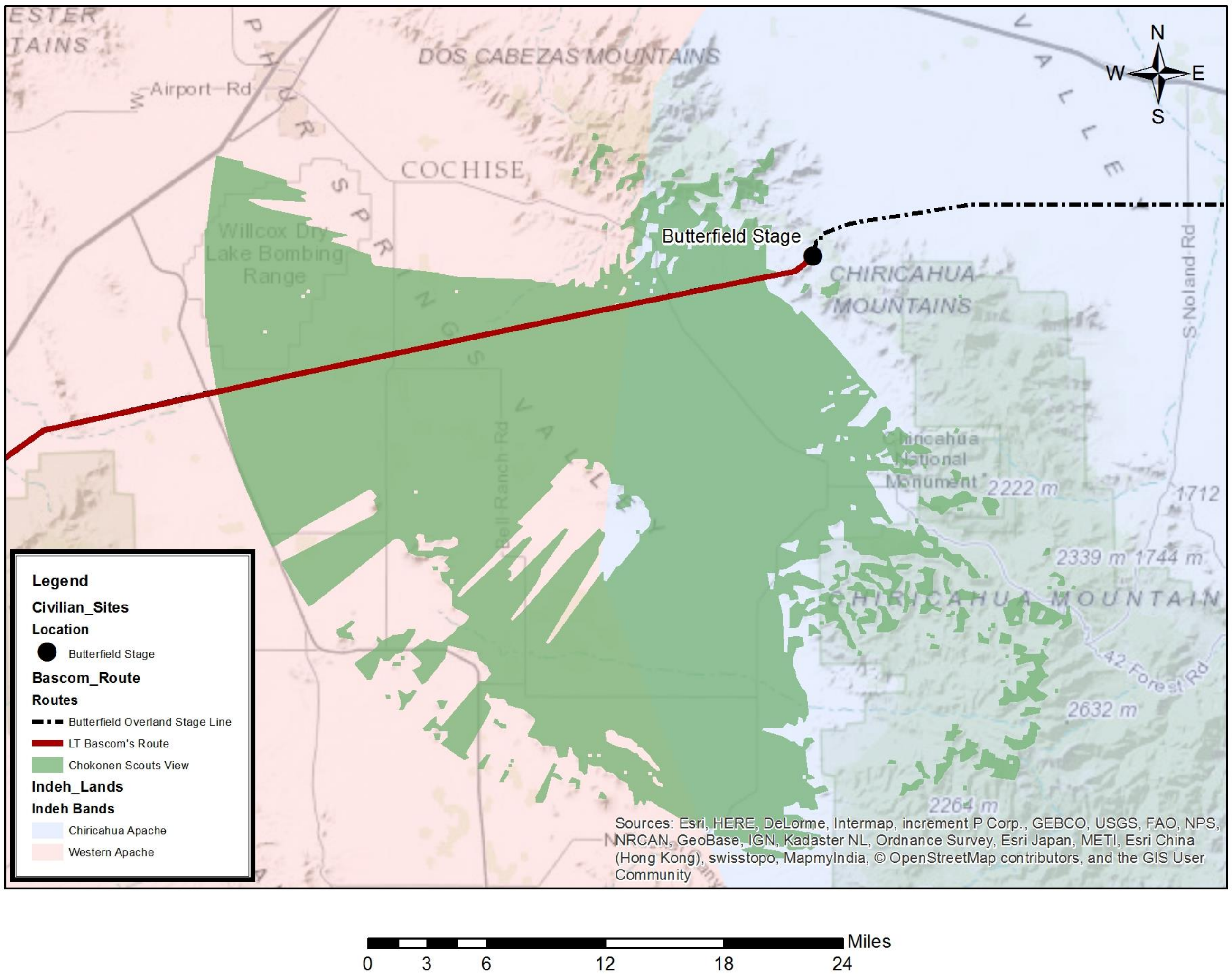
The Arivaipa Group of the Western Apache Band



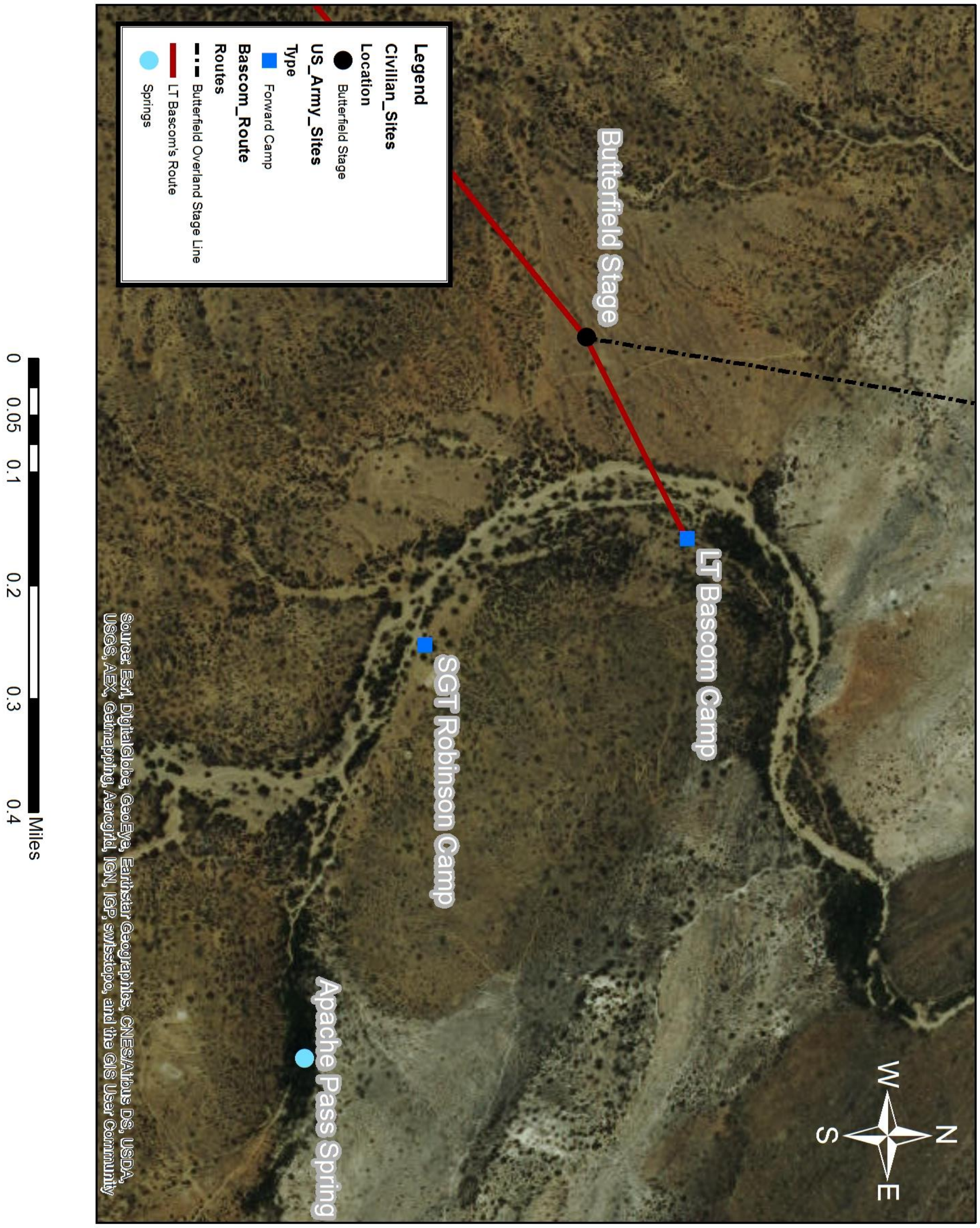
The Bascom Affair



Line of Sight Analysis Approaching Apache Pass



United States Army Positions at Apache Pass



Appendix E: Dynamic Research Tool

The University of Southern California, Spatial Sciences Institute will continue to host the study's dynamic tool on their Esri organizational account through May 2019. To access the story map used in the study go to the link provided below:

http://uscssi.maps.arcgis.com/apps/MapSeries/?appid=0dacfa88833b4c509fbafaed0ce22941

Appendix F: Study Examination Tool

THE BASCOM AFFAIR – Examination

Participant ID:_________
Time Completed:________

Standards Assessed:
Based on Hawaii Content and Performance Standards III for Social Studies

- ***Standard 1: Historical Understanding:*** *Change, Continuity, and Causality – Understand change and/or continuity and cause and/or effect in history*
- ***Standard 2: Historical Understanding:*** *Inquiry, Empathy, and Perspective – Use the tools and methods of inquiry, perspective, and empathy to explain historical events with multiple interpretations and judge the past on its own terms*
- ***Standard 6: Cultural Anthropology:*** *Systems, Dynamics, and Inquiry – Understand culture as a system of beliefs, knowledge, and practices shared by a group and understand how cultural systems change over time*
- ***Standard 7: Geography:*** *World in Spatial Terms – Use geographic representations to organize, analyze, and present information on people, places, and environments and understand the nature and interaction of geographic regions and societies around the world*

Section One: Fill in the blank (10 questions – 1 pt each)

1) **The Apache refer to themselves as the ________________.**
2) **John Ward's ranch is near present day ________________, in the state of ________________.**
3) **Felix Ward was kidnapped by the ________________ Apache, belonging to the ________________ Apache Band.**
4) **John Ward blamed Cochise, chief of the ________________ Apache, for the raid on his ranch.**
5) **Cochise was a member of the ________________ band of Apache.**
6) **Cochise spoke fluent ________________, and ________________.**
7) **Apache Pass is located in the ________________ Mountains.**
8) **Cochise permitted the ________________ to cross through Apache Pass.**

9) **Lieutenant Colonel Morrison was the commanding officer at ________________.**

10) **Lieutenant Bascom represented the________________ when he arrived at Apache Pass on February 3, 1861.**

Section Two – True or False (2 questions – 1 pt each)

11) **The Bascom Affair took place in Arizona?**

12) **The Apache bands shared a common form of governance similar to the United States model?**

Section Three – Short Answer (2 questions – 1 pt each)

13) **Which Apache band claimed the region in the vicinity of John Ward's Ranch?**

14) **Which Apache groups did Cochise turn to for support following the capture of his family at Apache Pass?**

Section Four – Spatial Analysis (6 questions – 1 pt each)

15) **Could Cochise see Lieutenant Bascom approaching Apache Pass with his company of 54 soldiers?**

16) **If you answered *yes* to question 15, approximately how far away was Lieutenant Bascom's company when Cochise was able to identify their movement? If you answered *no*, what prevented Cochise from identifying Lieutenant Bascom's approach?**

17) **How far did Lieutenant Bascom Travel to reach Apache Pass?**

18) **What was the distance between Apache Pass and the location where Felix Ward was taken?**

19) **What was the nearest United States controlled city to Apache Pass?**

20) **What is the distance between the city identified in question 19 and Apache Pass?**

Section Five – Essay (4 questions – 5 pts each)

1) **Where did the Apache live in 1861?**

2) In your own words, describe the events that led the United States and the Apache to war in 1861?

3) Were Lieutenant Colonel Morrison and Lieutenant Bascom justified in their assumption of Cochise's involvement? Why or Why not?

4) **Do you think that Cochise knew about the kidnapping before Lieutenant Bascom confronted him at Apache Pass? What indicators support your argument?**

Section Six – Study Assessment (0 pts each – research assessment only)

Did you review/access the research tools between sessions?

If yes, how often (how many times)? How many hours (*approximately)* did you spend using the research tool outside of the classroom?

Why did you, or didn't you choose to access the materials between sessions?

If you were in the experimental group, which medium(s) did you use to access the story map (Computer internet browser, tablet, smart phone, or a combination of the three)?

Did you look for any outside resources about the Bascom Affair?

If yes, what kind of resources did you pursue?

Thank you for your participation. Please remember to record your participant ID on the Front of the exam. If you forgot your ID, your teacher can provide it when you submit your exam.

Appendix G: Study Exam Tool Grading Rubric

This rubric defines the criteria used by the study to assess student responses to the exam tool's essay questions. The study targeted specific Hawaii Content and Performance Standards in each question, and used the stated performance benchmarks to evaluate levels of critical thought based on Bloom's taxonomy as revised by Krathwohl in 2002.

Essay Question #1: Where did the Apache live in 1861?

Hawaii Content and Performance Standards Targeted:

<table>
<tr><td colspan="2">Standard 2: Historical Understanding: Inquiry, Empathy, and Perspective – Use the tools and methods of inquiry, perspective, and empathy to explain historical events with multiple interpretations and judge the past on its own terms</td></tr>
<tr><td>Hawaii Benchmark: No benchmarks identified</td><td>Study Benchmark: Examine the Bascom Affair from multiple perspectives: American and Apache</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Identifies their own preconceived biases, articulates how the principal actors perceived the events leading up to the conflict at Apache Pass, and critical differences in each narrative that shape the way the event is viewed today.</td></tr>
</table>

<table>
<tr><td colspan="2">Standard 7: Geography: World in Spatial Terms – Use geographic representations to organize, analyze, and present information on people, places, and environments and understand the nature and interaction of geographic regions and societies around the world</td></tr>
<tr><td>Hawaii Benchmark:
SS.11.7.1 – Trace changing political boundaries under the influence of European Imperialism</td><td>Study Benchmark: Trace changing political boundaries under the influence of American Western Expansion</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Examines the new political boundaries created by American Western Expansion in the present day American Southwest.</td></tr>
<tr><td>Hawaii Benchmark:
SS 11.7.2 – Use tools and methods of geographers to understand changing views of world regions</td><td>Study Benchmark: Use tools and methods of geographers to understand changing views of the present day American Southwest</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Uses geographic visualization methods to understand changing conceptions of the present day American Southwest.</td></tr>
</table>

Performance Assessment:

Recall: Student response indicates a basic understanding that the Apache people lived in Arizona and New Mexico; however lack understanding of the changing perceptions of political boundaries over time or account for the Apache point of view.

Understanding: Student provides detailed descriptions of the surrounding terrain and political boundaries from the United States' perspective; however, continue to lack temporal understanding of the changing perception of political boundaries over time or account for the Apache point of view.

Analyze: Student response indicates a basic sense of conflicting land claims between the United States and Apache, but fails to demonstrate awareness of temporal change; student response reflects current United States' bias and fails to fully account for the Apache point of view.

Evaluate: Student demonstrates a clear understanding of changing conceptions of the present day American Southwest, and accurately identifies the land as the Arizona and New Mexico Territories; however, student response fails to account for the Apache view of the land and continues to relay United States' bias

Create: Student response indicates that the student accounts for the Apache perspective of the land as they saw it in 1861; response provides evidence that the student overcame their pre-conceived notions of space based on modern interpretations of political boundaries and land ownership.

Essay Question #2: In your own words, describe the events that led the United States and the Apache to war in 1861?

Hawaii Content and Performance Standards Targeted:

<table>
<tr><td colspan="2">Standard 1: Historical Understanding: Change, Continuity, and Causality – Understand change and/or continuity and cause and/or effect in history</td></tr>
<tr><td>Hawaii Benchmark: No benchmarks identified</td><td>Study Benchmark: Examine the events that led to war between the United States and Apache in 1861</td></tr>
<tr><td colspan="2">Sample Performance Assessment:
The student:
Identifies the relationship between the United States and the Apache in 1861 prior to Bascom Affair, and articulates the connections between the kidnapping of John Ward's son, and the actions taken by the United States Army that led to war.</td></tr>
</table>

Standard 2: Historical Understanding: Inquiry, Empathy, and Perspective – Use the tools and methods of inquiry, perspective, and empathy to explain historical events with multiple interpretations and judge the past on its own terms	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine the Bascom Affair from multiple perspectives: American and Apache*
Sample Performance Assessment: The student: Identifies their own preconceived biases, articulates how the principal actors perceived the events leading up to the conflict at Apache Pass, and critical differences in each narrative that shape the way the event is viewed today.	

Standard 6: Cultural Anthropology: Systems, Dynamics, and Inquiry – Understand culture as a system of beliefs, knowledge, and practices shared by a group and understand how cultural systems change over time	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine how failure to understand and account for culture exacerbated conditions between the United States and Apache*
Sample Performance Assessment: The student: Identifies cultural misunderstandings that escalated tensions to the point of war and is able to discuss opportunities for intervention that both parties missed.	

Performance Assessment:

Recall: Student response provides a basic review of the main events leading to war; however lacks understanding of the existing relationship between the U.S. and Apache, how the events relate, and a broader sense of how the role of culture influenced the outcome at Apache Pass.

Understanding: Student response provides a detailed description the events leading to war; however continues to lack understanding of the existing relationship between the U.S. and Apache, how the events relate, and a broader sense of how the role of culture influenced the outcome at Apache Pass.

Analyze: Student reflects a basic understanding of how the kidnapping of Felix Ward and the false accusation against the Chokonen resulted in conflict; however student response indicates confusion over how cultural misunderstandings influenced U.S. actions, and fails to account for conditions between the U.S. and Apache prior to 1861.

Evaluate: Student articulates a detailed understanding of the multiple layers of actions that led to war on both sides, and indicates how failing to understand the Apache culture caused the U.S to miss opportunities for peaceful resolution; however, student response does not consider the event in the broader context of the pre-existing relationship between the U.S. and Apache in 1861.

Create: Student response considers both points of view, and indicates a clear understanding of the events that led the U.S. and Apache to war in 1861; student defines how failure to comprehend Apache culture influenced the U.S. and places the events in the context of the relationship between the U.S. and Apache in 1861.

Essay Question #3: Were Lieutenant Colonel Morrison and Lieutenant Bascom justified in their assumption of Cochise's involvement? Why or Why not?

Hawaii Content and Performance Standards Targeted:

Standard 1: Historical Understanding: Change, Continuity, and Causality – Understand change and/or continuity and cause and/or effect in history	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine the events that led to war between the United States and Apache in 1861*
Sample Performance Assessment: The student: Identifies the relationship between the United States and the Apache in 1861 prior to Bascom Affair, and articulates the connections between the kidnapping of John Ward's son, and the actions taken by the United States Army that led to war.	

Standard 2: Historical Understanding: Inquiry, Empathy, and Perspective – Use the tools and methods of inquiry, perspective, and empathy to explain historical events with multiple interpretations and judge the past on its own terms	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine the Bascom Affair from multiple perspectives: American and Apache*
Sample Performance Assessment: The student: Identifies their own preconceived biases, articulates how the principal actors perceived the events leading up to the conflict at Apache Pass, and critical differences in each narrative that shape the way the event is viewed today.	

Standard 6: Cultural Anthropology: Systems, Dynamics, and Inquiry – Understand culture as a system of beliefs, knowledge, and practices shared by a group and understand how cultural systems change over time	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine how failure to understand and account for culture, exacerbated conditions between the United States and Apache*
Sample Performance Assessment: The student: Identifies cultural misunderstandings that escalated tensions to the point of war and is able to discuss opportunities for intervention that both parties missed.	

Standard 7: Geography: World in Spatial Terms – Use geographic representations to organize, analyze, and present information on people, places, and environments and understand the nature and interaction of geographic regions and societies around the world	
Hawaii Benchmark: *SS.11.7.1 – Trace changing political boundaries under the influence of European Imperialism*	**Study Benchmark:** *Trace changing political boundaries under the influence of American Western Expansion*
Sample Performance Assessment: The student: Examines the new political boundaries created by American Western Expansion in the present day American Southwest.	
Hawaii Benchmark: *SS 11.7.2 – Use tools and methods of geographers to understand changing views of world regions*	**Study Benchmark:** *Use tools and methods of geographers to understand changing views of the present day American Southwest*
Sample Performance Assessment: The student: Uses geographic visualization methods to understand changing conceptions of the present day American Southwest.	

Performance Assessment:

Recall: Student adopts a weak position; response confuses the relationship between events leading up to the Bascom Affair, displays pre-existing bias that fails to account for the existing conditions in 1861 and the role of culture, and fails to consider the implications of geographic space.

Understanding: Student defends their position using evidence from the lesson, but evidence lacks a clear connection to the argument; student response still lacks consideration of geographic space, and a clear understanding of how events prior to 1861 shaped the U.S. response or how failing to contend with Apache culture influenced U.S. assumptions of guilt.

Analyze: Student responds using evidence from the lesson that clearly supports their position; however, response relies on current events and fails to overcome initial bias to consider the historical context of the event or how U.S. actions were influenced by a lack of cultural awareness.

Evaluate: Student response uses persuasive evidence that indicates a clear understanding of missed opportunities for a peaceful resolution had the U.S. understood the Apache culture; however, response still portrays clear evidence of student bias and fails to contend with the events from the U.S. perspective in the historical context.

Create: Student response indicates that they overcame their personal bias to analyze the event from Morrison and Bascom's perspective; response considers the events in the context of the historical setting and reflects an understanding of how failing to account for Apache culture impacted their ability to assess how geographic distance between the Western and Chiricahua Apache bands influenced Cochise's knowledge of the kidnapping event.

Essay Question #4: Do you think that Cochise knew about the kidnapping before Lieutenant Bascom confronted him at Apache Pass? What indicators support your argument?

Hawaii Content and Performance Standards Targeted:

Standard 1: Historical Understanding: Change, Continuity, and Causality – Understand change and/or continuity and cause and/or effect in history	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine the events that led to war between the United States and Apache in 1861*
Sample Performance Assessment: The student: Identifies the relationship between the United States and the Apache in 1861 prior to Bascom Affair, and articulates the connections between the kidnapping of John Ward's son, and the actions taken by the United States Army that led to war.	

Standard 2: Historical Understanding: Inquiry, Empathy, and Perspective – Use the tools and methods of inquiry, perspective, and empathy to explain historical events with multiple interpretations and judge the past on its own terms	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine the Bascom Affair from multiple perspectives: American and Apache*
Sample Performance Assessment: The student: Identifies their own preconceived biases, articulates how the principal actors perceived the events leading up to the conflict at Apache Pass, and critical differences in each narrative that shape the way the event is viewed today.	

Standard 6: Cultural Anthropology: Systems, Dynamics, and Inquiry – Understand culture as a system of beliefs, knowledge, and practices shared by a group and understand how cultural systems change over time	
Hawaii Benchmark: *No benchmarks identified*	**Study Benchmark:** *Examine how failure to understand and account for culture exacerbated conditions between the United States and Apache*
Sample Performance Assessment: The student: Identifies cultural misunderstandings that escalated tensions to the point of war and is able to discuss opportunities for intervention that both parties missed.	

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<tr><td colspan="2">Standard 7: Geography: World in Spatial Terms – Use geographic representations to organize, analyze, and present information on people, places, and environments and understand the nature and interaction of geographic regions and societies around the world</td></tr>
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<tr><td colspan="2">Sample Performance Assessment:
The student:
Uses geographic visualization methods to understand changing conceptions of the present day American Southwest.</td></tr>
</table>

Performance Assessment:

Recall: Student adopts a weak position; response confuses the relationship between events leading up to the Bascom Affair, displays pre-existing bias that fails to account for the political subdivisions of the Apache in 1861, and fails to consider the implications of geographic space on Cochise's sphere of influence.

Understanding: Student defends their position using evidence from the lesson, but evidence lacks a clear connection to the argument; student response still lacks consideration of geographic space, and a clear understanding of how events prior to 1861 shaped the Apache response or how Apache political divisions would have influenced Cochise's knowledge of the event.

Analyze: Student responds using evidence from the lesson that clearly supports their position; however, response relies on current events and fails to overcome initial bias to consider the historical context of the event or how Apache political divisions influenced the knowledge Cochise had access to prior to Bascom's arrival.

Evaluate: Student response uses persuasive evidence that indicated a clear understanding of Cochise's frame of mind entering the meeting with Bascom; however, response still portrays clear evidence of initial bias (Cochise as the chief of the Apache as opposed to chief of a small sub-group of the Chiricahua band) and fails to contend with the implications of geographic distance between the Western and Chiricahua Apache bands.

Create: Student response indicates that they overcame their initial bias to analyze the event from Cochise's perspective; response considers the events in the context of the historical setting and reflects an understanding of how Apache political divisions and the geographic distance between the Western and Chiricahua Apache bands influenced Cochise's knowledge of the kidnapping event.